THE THREE PRIME FACTORS IN SUCCESSFUL PACKAGING*

By E. C. EMANUEL

Chief Chemist, Glass & Closure Products, Armstrong Cork Company, Lancaster, Pa.

IN THE successful packaging of any material, there are three main factors for the producer to consider: the product, the container, and the closure.

Although attractive closures, labels, wrappings, seals and cartons are important from a sales standpoint, they do not contribute to the keeping qualities of the product.

The three major factors are, to repeat, first, the product itself, second, the container, and third, the closure.

The product may be powder, liquid, or solid. It may be neutral or have an acid or alkaline hydrogen-ion concentration. It may contain water, alcohol, the higher alcohols, organic solvents, oils, fats, or waxes, organic or inorganic salts, essential oils, etc., or complex combinations of any of the above. The product may react with the container or with the closure; therefore, great care must be exercised in the choice of these for proper results.

The container may be glass, metal, paper, molded material, or a special type not requiring closures, such as cellophane, Vinylite, Pliofilm or other synthetic wrappings.

The closure may be a friction fit lid for a metal container, a ground glass stopper, or a plug or stopper type of closure such as corks, screw caps produced from various metals, or molded caps. During the war period, closures were produced from paper, wood and other available materials. Paper closures have neither the utility nor the attractive appearance of either the molded or metal caps, consequently are not in general use.

By far the most generally used closures are those with internal screw threads. Prior to 1919, each cap manufacturer and some closure users designed their own thread contours and designated the number of threads per inch and other dimensions. After the First World War, standardization in many fields was considered, and studies were undertaken in the Glass Container Association—now the Glass Container Manufacturers Institute—to develop standards for the entire glass industry in the various diameters of

---

* Presented at the May 15, 1946, Meeting, New York City.

closures and styles of finishes commonly manufactured. A number of types were obsoleted and standards set up which have been well accepted by the glass container manufacturers and the trade. This standardization has enabled the glass manufacturers to work to closer tolerances, and permits a user to buy either closures or containers from two or more sources of supply and be sure that the closures will fit the containers of any manufacturer, or *vice versa*. The Standardization Committee of G.C.M.I. is still quite active in improving present finishes and approving suggested changes.

Screw caps consist of two component parts, namely, the cap itself and the liner. The caps may be made from metal or from synthetic molding materials.

Before the war, metal caps were produced of tinplate, aluminum or terneplate. Some closures were made from brass or nickel-plated brass, though these were not considered "standard" closures for the general industry. They do find extensive use in the Toiletries Industry. Terneplate consists of steel coated with a lead alloy, and has not been used generally for cosmetic or food purposes, due to the high lead content. Owing to the scarcity of tin during the war, it was necessary that its use be curtailed; consequently, only highly essential items were permitted the use of tinplate. The closures were produced from black iron and bonderized black iron. Closures made from substitute materials are subject to rusting when exposed to conditions of high humidity or corrosive preparations. The protective coatings, either oleoresinous or synthetic, do not sufficiently protect black iron or bonderized blackplate from rust. Frequently under-film corrosion develops, in which the rust develops beneath the protective coating, since moisture-vapor penetrates through the coating. The protective coatings adhere better to the bonderized plate than to the plain black iron. It must also be remembered that during the war period raw materials for protective finishes were scarce, and many substitutions had to be made which did lower the quality of the protective finishes.

Tinplate, while it will rust under adverse conditions, has stood up very well in general use. During the war, the electro-tinning of plate was developed, whereas, formerly, the hot-dip practice was used. In this latter method, approximately $1^1/_4$ to $1^1/_2$ lbs. of tin were applied to a base box of steel plate. By the electro-tinning method, equivalent rust protection can be developed by the use of $^3/_4$ lb. of tin per base box, or somewhat less. When tin again becomes available, electro-tinplate will be used generally for screw caps.

Prior to the war, a sizable quantity of caps was produced from aluminum, although the cost was somewhat greater than tin. Should aluminum be equivalent in price to tinplate, it will find considerable use in the post-war period. Aluminum will be attacked by alkaline products and by certain inorganic salts, though the corrosion products of aluminum are generally white in color and not as unsightly as the brown iron rust which develops on black iron or sometimes on tinplate.

Protective coatings for metal plate are used both on the inside and outside of the caps. For aqueous products, an oleoresinous type is generally used, though synthetic coatings are available which have good alcohol, acid and alkaline resistance. Similar coatings may be applied on the outside of the metal, or the metal base may be lithographed and, if lithographed, is protected by a clear coating over the lithography. Very attractive colors varying from black through the solid colors and pastel shades to white can be used.

In the manufacture of metal caps, the protective coatings are applied to the plate in the flat, and from the decorated plate blanks, generally of the shape of a stiff straw hat, are first produced. These blanks are then put into thread rolling machines which turn the bead, form the thread, and form the knurl if knurled caps are being produced. Knurling increases the finger hold and aids in the removal of closures. The knurling tools tend to rupture the coating and form focal points which can develop corrosion, though on the inside of the cap the exposed portions are generally protected by the liner and under normal storage the outside does not develop rust.

It is interesting to note that the protective coatings and decorations are applied to the flat sheet. The sidewall of the blank in which the threads are formed is subject to some stretch during the punching operation. This stretches the coating, and the coating is then further stretched when the threads are formed in the closure. It is really remarkable that, under this drastic treatment, protective coatings have been formulated which will take the stretch, remain properly adhered to the metal, and afford additional protection against rust.

Metal caps are produced in sizes from 15 to 120 mm. The smaller sizes are more difficult to make and control to accurate dimensions, though closures from 18 mm. on up are quite satisfactory.

Molded closures are relatively newcomers in the closure field, being about twenty years old. They are produced from compounded synthetic resins, and are of two types, namely, the thermosetting or those made from thermoplastic materials.

Molded closures are produced to accurate dimensions, and these dimensions depend upon the accuracy to which the molds themselves are made, for the molding materials faithfully reproduce the various contours of both the cavities and force plugs which form the outside and the inside portion of caps. All molding materials shrink to some degree on cooling; however, allowances for this are made in the manufacture of the tools, so that accurate caps are produced.

The most generally used thermosetting molding material is of the phenol formaldehyde resin type.

The resin is filled with wood flour as an extender, with pigments and lubricants added. The standard type of wood flour filled material is available in the solid colors, though pastel shades cannot be produced since the resin is inclined to be dark in color. This type of compound has good resistance to atmospheric moisture and will withstand steam autoclaving, though with some loss of gloss and a tendency toward roughness in the finished piece. Mineral-filled compounds are available at a considerable increase in cost, which will withstand steam sterilization.

The urea formaldehyde resins lend themselves to the molding of caps in the white or pastel shades. Alpha cellulose is generally used as the filler with the urea formaldehyde resins. Such caps have adequate moisture resistance for general use, but tend to chalk or change color when immersed in water, and do not resist steam sterilization. Originally the urea formaldehyde caps were inclined to be slightly translucent, and when a liner with backing which was opaque or dark in color was applied in the cap, the top portion would appear to be darker in shade than the sidewall. This condition can be corrected by using a more nearly opaque molding material or, in some cases, a lighter colored backing material, if available.

Melamine resins are currently being placed on the market. These can be produced in pastel shades and have excellent water resistance—in fact, will stand steam sterilization. Currently, they are high in cost.

The thermoplastic molding materials are just what their name implies, that is they soften with heat, even after molding. The thermoplastic materials which have been used are cellulose acetate, cellulose aceto-butyrate, methyl methacrylate, Vinylite, and polystyrene. Polystyrene has been used for the production of closures due to its excellent acid and alkali resistance. It is also quite resistant to moisture attack. Transparent closures may be produced, though, generally speaking, they are unsightly on the package, due to the fact that the bottle finish threads and liner are readily apparent through the transparent materials, which does not add attractiveness to the package. These materials are available for the production of opaque closures. The thermoplastic materials are all soluble in organic solvents; consequently, they do not lend themselves too well to use with perfume or toilet waters containing essential oils. While the closure itself may not, during the shelf life, be exposed to the contents of the container, during first use some of the product will remain on the thread and may then soften the inner portion of the cap. In use with perfumes, some of the product may remain on the finger, and when the cap is again applied to the container, the essential oil may remain on the outside, being less volatile than the solvents contained in the product, and cause a softening of the molded part.

Molded caps can be produced in very attractive styles and a wide variety of shapes, though tapers or shapes in which the diameter at the top of the closure is greater than the diameter at the base where the closure is screwed into place on the bottle, should be avoided. To make reverse tapers, very complicated molds are required, which slows down production and increases the cost of the cap.

The liner for the closure is equally as important as the closure itself, and is considerably more complex. The liner acts as a more or less resilient gasket which the cap compresses and holds against the bottle; the liner must make an efficient mechanical seal and re-seal. It must be of such physical and chemical nature that it will not disintegrate or lose its efficiency even when the packages remain on the retailers' shelves over considerable periods of time. The liners in metal caps are not adhered in the closure. They are made somewhat larger in diameter than the threads, and in lining the cap, they are forced in past the threads into a recess in the top of the cap. It is the general practice to adhere the liners in molded caps for here the liner is somewhat smaller than the thread diameter. Liners may be divided into two fundamental classes: (a) homogeneous and (b) duplexed or faced.

Homogeneous liners, such as natural cork, cork composition, rubber and the special solvent type materials used to retain organic solvents, are generally used for special purposes. Natural cork and cork composition may be used as liners for oils in the medium or high viscosity range, and for products sold quickly, where the shelf life is not over six months. In the case of products that contain organic solvents, natural cork and cork composition are not generally recommended.

Rubber liners find general use for alkaline preparations, for the hypochlorites and certain acids. Solvent liners are indicated where organic solvents are to be retained, such as nail polish, corn cures, and collodion. These homogeneous liners are the only type which should be employed with molded caps utilizing a post or a well, for a quill brush, glass rod or other type of applicator.

Duplexed liners, that is, those with facings applied to a backing material, are not suited for post or well type caps since the efficiency of this type liner depends upon the facing material employed. In a post or well type cap, the liquid will contact the backing material, since a gasket liner is used for such caps, and the liquid can pass through the center hole in the liner at the juncture of the post or well.

The liners most generally used in screw caps are of the duplexed type. These comprise a facing material and a backing material. The backings consist of newsboard, pulpboard or various types of cork composition. Years of experience have indicated that newsboard with proper facing will produce an effective seal for products which are not highly volatile, and this type of liner is quite generally used for jar covers. Pulpboard is light in color and has been used in the past for lining semi-translucent urea formaldehyde caps in order not to cause two shades in the cap, as mentioned previously. Currently, pulpboard is very difficult to obtain, stocks in this country being now practically non-existent. Should the facing material be broken due to a fin on the glass container or due to penetration or action by the product, and pulpboard or newsboard be used as a backing, loss of product will result. Cork composition is, in itself, a satisfactory liner for many products where the shelf life is short. With added protection from the facing, cork composition, though more expensive, produces the most efficient seal. Should the facing be ruptured or impaired, the cork composition then acts as a secondary seal. The usual cork compositions are produced from granulated cork and a protein binder. Where indicated, cork compositions can be supplied with a resinous binder.

The facing materials for liners are the metallic foils, varnished papers or synthetic films. Tinfoil, 99.7% pure, 0.0015″ thick, mounted on white sulphite paper, has been used for organic solvents and alcohol-containing preparations. Such a liner is indicated for nail polish removers, perfumes, colognes, and products which do not etch or attack the foil. If the finish and sealing surface of the glass container is in good condition, newsboard may be used as a backing; otherwise, cork composition is indicated. Currently, Tinfoil is unobtainable for such products, and during the war a urea formaldehyde-alkyd coating on paper producing a varnished paper type of liner was used. This liner is definitely inferior to Tinfoil, but was used during the emergency. Dead soft Aluminum Foil, 0.001″ thick, backed with cork composition, has been tried as a substitute for Tinfoil with rather poor results, due to the fact that the Aluminum Foil is not as soft as Tin, and does not give intimate contact with the glass and prevent evaporation.

The manufacturers are currently attempting to produce Aluminum Foil with an organic coating such as Vinylite applied to the face. Early tests have indicated that an efficient liner will result if the product does not dissolve the organic coating which has been applied to the Aluminum Foil.

The varnished papers—which are just what their name implies, namely, a varnish applied to a supporting paper or several coats of varnish being built up to yield the necessary thickness—have been used for many years as facings. There are many types, such as Pale Yellow Oil, Yellow Oil or Light Brown Oil, Black Alkali Paper, Harvel, Brown Acid Resisting Paper, 8018, etc. The varnished papers have fair moisture-vapor transmission characteristics and are satisfactory for aqueous products and cold creams. Black Alkali Paper will withstand 50% alcohol solutions, although the varnished papers are definitely attacked by essential oils or products containing the essential oils. A wax coating applied to the varnished paper improves the moisture transmission characteristics, though the wax tends to hold carton dust, and the dust developed in manufacturing operations, and may at times flake and show up as floating particles on the product.

Vinylite, the copolymer of vinyl acetate and vinyl chloride plasticized and pigmented, has been applied to a white sulphite paper to produce an excellent facing material and has enjoyed quite general use. The Vinylite resin is dissolved by the ketones, consequently it cannot be used with nail polish or nail polish removers and is attacked by certain perfumes. Vinylite has good moisture-vapor transmission characteristics. During the war period, this lining material was decidedly scarce, although it is currently available in reasonable amounts.

Before the war, Panaseal was a very active competitor of Vinylite. It consists of the product Pliofilm (a rubber hydrochloride compound) mounted on white sulphite paper. This material was also soluble in the ketones and in the chlorinated hydrocarbons, as well as the hydrocarbons, and was attacked by certain perfumes. It has good moisture-vapor transmission characteristics, and was used in jar covers for cold creams.

A urea formaldehyde-alkyd resin type of varnish was applied to white sulphite paper by several concerns under the trade names Silite, Whiteseal and Impervite, and used as a replacement for Tinfoil, Vinylite and Panaseal during the war. The film is inclined to be somewhat brittle and does not have much stretch. It is best used with a nonresilient type of backing such as newsboard, and is used as a substitute for Tinfoil in many applications.

The newer synthetic resins such as Saran, Polythene and Nylon will, in the future, enter the liner field. At the present time they are either too expensive, have not been produced in sufficiently thin films, or have too great odor or taste transmission tendencies. They do have some admirable resisting characteristics, and a serious effort is being made to utilize them for the development of a more nearly universal type of liner.

Some concerns have used waxed pulpboard as a liner for cold creams. This is probably as cheap a light colored liner as can be obtained. Its efficiency is low and its moisture-vapor transmission characteristics also are poor. Saturated pulpboard consists of pulpboard impregnated with a wax and oil combination. This type of liner has been used for cold creams, and is better than the waxed pulp, but is really not ideal. Quality white waxed paper consists of white sulphite paper with an application of paraffin or microcrystalline wax. It has been used mounted on pulpboard or on saturated pulpboard, and has fair moisture-vapor transmission characteristics. It is white in color, although not as efficient as Vinylite or Panaseal mounted on pulpboard or newsboard. Since the liner represents a very small factor in total package cost, price consideration should have very little influence on the manufacturer's selection of the liner to protect his product. Unless the liner provides maximum protection for the product, it is worthless at any price. Furthermore, while a liner may satisfactorily seal a product marketed by one manufacturer, it does not follow that another product of similar nature (but with a slight change in formulation) will be satisfactorily sealed with the same type of liner. To obtain the most dependable liner, laboratory recommendations by the cap manufacturer should be obtained and the cap manufacturer's recommendation should, in turn, be checked by the laboratory of the manufacturer who packages the merchandise. Often it is desirable to run tests for extended periods of time.

Screw caps should be applied to containers with a proper tightening force. With too little force, the liner may not be properly seated and leakage may result. With too great force, the threads or top finish in metal caps may be distorted and molded caps may be broken. Again, if the caps are too tightly applied, they may be difficult to remove, causing customer dissatisfaction.

Studies conducted by the Pittsburgh Testing Laboratory for one of the cap companies, indicated that the average housewife could exert a force on a 28 mm. cap equivalent to 33 lbs. tangential, or 17.95 torque inch pounds to remove a screw finish cap. This force is therefore the maximum that should be applied, and laboratory experience has indicated that it is not necessary to reach this limit to produce an effective seal with properly chosen liners and good glass finish. The torque inch pounds, of course, will depend upon the diameter of the cap and the number of threads per inch, and will vary from 4.75 torque inch pounds in a 15 mm. cap to 95 lbs. for 120 mm. caps. Waxed liners reduce the friction between the liner itself and the glass finish; consequently, the caps can be applied further than normal, and the application of caps with such liners should be studied carefully to avoid excessive tightening.

As has been indicated, the liners can be attacked by various products. This is also true of glass containers. The better glass companies now produce glass which is of good chemical durability. The common container glass several years ago was quite high in soda, and would cause a change in pH in a neutral product. As a matter of fact, some of the glass would show a definite alkaline reaction to phenol-phthalein when arbon dioxide-free distilled water was placed in the bottle, and the bottle then placed in a water bath and the temperature raised to 90°C. and held for one hour. The glass which showed this reaction would definitely produce flakes or spicules in water or in 50–50 alcohol and water.

A product having a pH of approximately 6.8 when packaged, after six months or a year or more at room temperature, might change to a pH of 8.5 or 9 and definitely show flakes. The smaller the container, the greater is the relative change, for the change depends on the surface-to-volume ratio. A 2 oz. bottle will show more alkali extract than will a 32 oz. container, since there is more surface with respect to the contents in a smaller container.

Glass with poor or low chemical durability will "weather" or show crystal growth on the inside surface when exposed to damp or humid conditions of storage before use. This crystalline growth has been considered as a mold growth by some observers, though culture tests and examination under a microscope definitely indicate that it is a condition on the glass surface due to the glass itself, and not due to mold. A dilute acid rinse has been used in the past to reclaim such containers, though glass of good chemical durability, low in alkaline extract, will not show the weathered condition.

Acid products do not show any attack and only a slight change in pH when packaged in glass of poor chemical durability, so it is possible to introduce organic acids such as malic, to lower the hydrogen ion concentration, and thus prevent the formation of flakes or precipitates due to the glass.

Borosilicate glasses are not alkaline in nature, consequently have good chemical durability. They are about five times more expensive than the better commercial glass containers and their use is indicated only for special biological and pharmaceutical use.

The three major factors in packaging have been discussed in some detail with special reference to the container and the closure.

It is apparent that there is a very close relationship of these three factors and each should be considered in relation to the other two. Best results can be obtained by close cooperation between the technical staffs of the customer and the producer of the closures and containers.