ONE PIECE HEAT SEALABLE FOLDING CARTONS: A STUDY OF CHARACTERISTICS AND SEALING METHODS

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ONE PIECE HEAT SEALABLE FOLDING CARTONS:
A STUDY OF CHARACTERISTICS AND SEALING METHODS

By

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AN ABSTRACT

One of the most distinct trends in modern packaging is toward the elimination of both inner liners and overwraps on packages used for dry and powdered products. This is being accomplished by the use of functional coatings, which means merely that the protective function of the package is provided by a material coated directly onto the carton board.

Due to the nearly perfect plastic surface presented by many of these coatings, sealing of the one piece package becomes difficult. Common adhesives are no longer adequate, and increased production speeds necessitate a much faster setting material.

Two solutions to the sealing problem for one piece folding cartons are presented. First, thermoplastic hot melt adhesives are employed, being applied in a manner similar to the application of standard adhesives. They are, of course, softened by heat and set upon cooling, thereby providing the setting speed necessary in modern production methods.

Secondly, a number of functional coatings being presently used are thermoplastic, and hence can be heat sealed or welded to a similarly coated surface. Therefore, a carbon coated on both sides with vinyl, polyethylene, or similar thermoplastic can be sealed by softening the coating by heat and subsequent cooling under pressure.

Presently in production are a number of liquid holding cartons using the principle of plastics welding in their sealing. The weldability of the coating materials used on these cartons was studied in terms of unique properties, and sealing methods used in production were discussed.

Tests were conducted on liquid holding cartons which employ the principle of plastics welding, and their functional characteristics were compared with similar wax-coated cartons sealed with adhesives. Significant differences could not be found in the ability of these cartons to withstand stressed conditions, but plastic coated cartons proved more acceptable according to customer survey studies conducted by the Dairy Department of Michigan State University. Time tests also showed that plastic coated cartons retain their liquid holding capacity for a greater length of time.

In this project, by observation and experimentation, it has become apparent that the adhering of thermoplastic materials and surfaces is an answer to many of the existing problems in the production of functionally coated one piece packages. With the adaptation of thermoplastic adhesives and weldable coatings to one piece folding carton production, these cartons can be produced at higher speeds with equal or greater integrity.

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INTRODUCTION

One of the most distinct trends in packaging today is toward the elimination of both inner liners and outer wraps in folding cartons. In order to accomplish this goal, packaging engineers must find a means of incorporating the protective function of the package into the carton board itself, thereby making a one piece folding carton.

Through functional coatings on carton board, this end has partially been served. These coatings, through research, become more highly water and grease resistant, and are steps in the development of one piece cartons. At the same time, these functional coatings provide a smoother, more plastic (non-porous) surface for offset printing, resulting in a more attractive package from the marketing standpoint.

Although the advantages of one piece functionally coated cartons are obvious in the areas of machinability, protection, and appearance, certain disadvantages are also apparent which must be resolved before the package can come into universal use.

As more highly water and grease resistant coatings are applied to carton board, the difficulty in adhering the board and sealing the carton increases. Faster machine production speeds and recent advances in packaging machinery necessitate faster setting adhesives. Carton sealing must be adjusted to the faster machines, new coatings on board, and automatic operations.

Two methods present themselves as possible solutions to the sealing problem for one piece folding cartons. First, the carton may be sealed with a thermoplastic adhesive of the hot melt type. The first part of this paper deals with thermoplastic adhesives and their application.

The second solution to the sealing problem of one piece folding cartons is the sealing of the coating itself without the use of adhesives. This, of course, is only possible where the coating is of a thermoplastic material, which can be welded or heat sealed to similar surfaces. The last part of this paper deals with the heat sealing of cartons continuously coated with such a thermoplastic material.

It is the purpose of this study to examine the sealing methods which are used with one piece folding cartons, to devise a means of testing the seals on these cartons, and to draw conclusions on these tests.

I. THE MECHANICS OF ADHESIVE SETTING

Introduction

"Adhesive" is a very general term which applies to any substance applied as an intermediate layer between two surfaces which tend to hold them together. The term includes cements, pastes, gums, animal glues, and mucilage. The term also includes plastic resins, waxes, and blends of waxes, resins, and solvents which make up thermoplastic adhesives, and which tend to hold together their substrates.

Two basic types of adhesion are utilized in the packaging industry. These types will be discussed in terms of their application to folding carton packaging.

Mechanical Adhesion

Mechanical adhesion is most important where porous substances such as wood, cloth, or paper are involved. Liquid adhesives are used to effect mechanical adhesion, which consist of a solid bonding agent carried in a fluid vehicle. This is true of most adhesives including the well-known semi-solid library paste, which, in spite of its consistency, uses water as a vehicle.

For adhesion to take place, then, the liquid vehicle must be removed in order that the solids be allowed to coagulate. This is accomplished either by evaporation of the vehicle or absorption into the substrate. In more porous materials, the latter is the most effective method. In bonding the surfaces of conventional folding carton board, mechanical adhesion is involved. Penetration of the liquid vehicle into the stock is accomplished, and consequently the strength and plasticity of the adhesive is not of prime importance.[1]

Adhesives presently used in packaging which utilize the principle of mechanical adhesion are as follows:

Vegetable adhesives which rely on strong cohesive bonds of dextrins, caused by the loss of its water vehicle.

Resin emulsions and latices are stable dispersions of adhesive solids in water. They set and form a bond when enough water is removed to cause the dispersion to break. An increase of the solids in dispersion to around 70% will result in the formation of a bond.[2]

Lacquers are similar to vegetable adhesives in that most or all of the liquid vehicle must be removed before a bond results. Any residual solvent acts as a plasticiser and lowers the cohesive strength of the substance.

Animal glue adhesives are a solid gel at room temperature and are run in production at elevated temperatures. The cohesive bond is formed by both cooling and by the loss of water. In many packaging operations the return to the gel state and its inherent tackiness is more important than the loss of water. All of the solvent must be removed, however, before the ultimate bond strength is reached.

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[1]L. J. Wood, Jr., Bleached Board Seminar, Packaging Institute 19th Annual Forum, October 28, 1957.

[2]Thomas Flanagan, "Faster Setting Adhesives Boost Production Line Speeds," Package Engineering, Vol. 3, No. 4, April 1958, p. 25.

Implications of the Nature of Mechanical Adhesion

Several limiting factors are present which cause packaging engineers to look critically at mechanical adhesion and the adhesives employing this principle.

First, the moisture content of the stock used in packaging has a direct relationship to the effectiveness of the adhesive. Since in most packaging applications the vehicle must soak into the stock, removal becomes more difficult as the moisture content of the paper increases. Soaking wet paper cannot be adhered for this reason, since there is no place for the water or vehicle to go.

Secondly, variations in density, porosity, and absorbency of stock has a great influence on the effectiveness of adhesives. More dense (less porous) stock has greater resistance to the passage of liquid and hence retards the removal of the vehicle from the adhesive. Supercalendared paper or paperboard is an example of a packaging material which should resist the passage of liquid because of its density.

The first criticism of mechanical adhesion in modern adhesive application is the difficulty encountered in attempting to adhere new coatings with adhesives having a limited affinity for the coating.

Specific Adhesion

The common denominator in the limitations of mechanical adhesion in packaging applications is the slow setting speed. This, of course, is due to the fact that the vehicle which carries the adhesive material must be completely removed before an effective bond results.

Specific adhesion, however, involves intermolecular forces at the interface between the adhesive and the substrate. Strength and plasticity of the adhesive film become the primary considerations rather than the molecular penetration of the adhesive into the substrate.

This type of adhesion is made necessary by impenetrable surfaces such as glass, polished metal, and plastic. Theoretically, unbalanced forces at the surface of these materials render it more active than the interior of the mass, making possible specific adhesion in a material which could not otherwise be adhered.

A dual problem then arises when attempting to seal folding cartons made from board which has been coated with plastic materials. In attempting to achieve the optimum in greaseproofness, moistureproofness, and printability, packaging engineers have made the surfaces of paperboard smoother and less porous. We then find that we can no longer use low cost adhesives employing the principle of mechanical adhesion, since we are attempting to seal a surface which will not allow the vehicle to be removed from the adhesive material.

Many of our recent developments in folding cartons present nearly plastic surfaces for sealing, and we must resort to adhesives which use a high strength plastic polymer as a base. This type of adhesive will remain fairly flexible, and will resist disruption of the adhesive bond by flexing and pressure on the flaps of a folding carton.

The Solution: Hot Melts

The adhesive material known as hot melt is a solid thermoplastic substance which contains no liquid vehicle and sets upon cooling alone.

It is 100% solid material which is melted down to a molten liquid by the application of heat. In packaging applications, it is applied in this liquid state and the second surface to be bonded is joined to it immediately, before the material has solidified.

The resolidification of the adhesive is all that is necessary to effect a bond, and this is caused by cooling alone. Hot melts do not pass through the jell state as do animal glues, but have a definite transition from liquid to solid. Room temperature does not affect the setting speed, since the entire operation is performed at high temperatures. Hot melts, being insoluble in water, are not affected by variations in relative humidity and very little by the moisture content of the substrate.[1]

The Nature of Hot Melts

How do not melts differ from waxes and asphalt and other thermoplastic materials? First, the basic difference is in the polymeric constituent in a hot melt which tends to give it a definite softening range over the transition from liquid to solid. Such high molecular weight polymeric materials contribute to the toughness and specific adhesion which is lacking in waxes and asphalt. (See Figure 1 below)

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[1]Thomas Flanagan, "Faster Setting Adhesives Boost Production Line Speeds," Package Engineering, Vol. 3 No. 4, April 1958, p. 25.

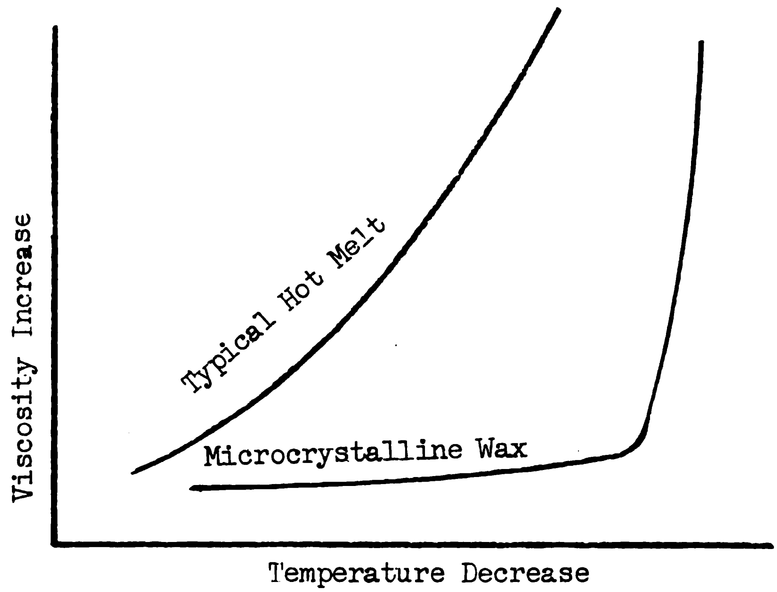

FIGURE 1. Relative comparison between viscosities of hot melt adhesives and waxes as temperature changes.[1]

A multitude of different types of hot melt thermoplastic adhesives have been developed and are becoming popular in various packaging applications. Most of these are blends of polymers, plasticisers, and oils, usually in emulsion form, which, at room temperatures, are whitish or cream colored solids resembling wax in consistency.

Many advantages are offered by the use of heat sealing thermoplastic adhesives in packaging applications. Let us compile some of these and examine them here:

1. Instant tack, and positive adhesion, due to the cooling property of the material.

2. Versatility on a wide variety of surfaces. Although hot melts are especially adapted to nearly plastic surfaces where specific adhesion is required, they are also equally adaptable to more porous surfaces, and result in a strong bond.

3. Production speeds using thermoplastic adhesives have been shown to increase two to three times.[2]

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[1]Ibid.

[2]National Starch Products Co., Technical Service Bulletin No. 305.

New applications of heat sealing with thermoplastics have not been thoroughly explored, although this type of sealing is presently being examined by a number of firms involved in extensive packaging operations.

Types of Heat Seals

Heat seals are either of the direct type or employ delayed tack. The direct heat seal has essentially no time delay characteristic, and must be activated and applied simultaneously to the surface being adhered by heat and pressure. Upon activation by heat, the adhesive coating will become tacky, but upon removal of heat it will lose its tack almost immediately.

Direct heat sealing is further divided into two principle classes. Some direct heat seals may be made by applying the adhesive to only one surface and then joining the coated part to the uncoated part. Other adhesives require that each face to be adhered must be coated, and then sealed "face to face."

Delayed tack heat seals occur in the use of adhesives which are activated upon application of heat, and remain tacky for some time. Once activated, they will adhere to most surfaces with the application of pressure alone. This time delay feature distinguishes this group of hot melts from those employing direct or instant bonding. An interesting feature of this type of heat seal is that in some applications where tension is not immediately put on the seal, a delayed tack heat seal may be used as a direct seal.

Factors Affecting Thermoplastic Adhesives

Successful heat sealing with thermoplastics depends essentially on four variables. An effective heat seal depends on reasonable control over these four elements:

1. Time--the period of dwell during which the heating element is in contact with the adhesive coated material.
2. Temperature--the surface temperature of the heating element, and theoretically the temperature of the adhesive in the molten state.
3. Pressure--the force which the heating or sealing element exerts on the stock, and consequently, the pressure of the stock on the adhesive layer.
4. Insulating effect--different weights of paperboard will have varying heat conductivity. If the weight of the board is lighter, it will usually permit a reduction in heat seal temperature.

Other factors which influence the integrity of heat seals are the adhesive film itself and the paper to which it is applied. Uniformity of the adhesive film is essential. Striated coatings, for example, often caused by direct roll application or simple knife coating, reduce the effective contact area. Fluctuations in film thickness will result in poor adhesion due to excessive or insufficient adhesive.

In addition to the weight or insulating effect of the paper, the adsorptive qualities of the paper should be such that a maximum of the adhesive remains on the surface and does not penetrate into the substrate.

Most of the functionally coated paperboard used today has this quality, which allows for better specific adhesion.

Application of Hot Melts

In packaging applications, the use of hot melt adhesives can result in increased production rates. One machine company reports loading five inch pies into cold wax printed cartons at speeds up to 265 per minute.[1] A somewhat similar technique is used in the cereal field, with a different cartoning machine recording production of 350 per minute.[2]

The hot melt adhesive is applied by intaglio glue rolls after a preheating of the end flaps. After adhesive application, the loaded carton passes into a flap folding station and then into a chilling section which replaces the drying conveyor of conventional machines. The end flaps are chilled so as to set the adhesive quickly, as well as to prevent further heating of the carton. The adhesive is applied around the periphery of the end flap, and is claimed to be "pretty close to a leakproof carton."[3]

The intaglio glue rolls, which are a recent development, are especially adapted to thermal application of hot melt adhesives. Their use gives an especially suitable pattern application around the periphery of the flaps, lending to the integrity of the package.

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[1]R. A. Jones and Company, Inc., Cincinnati, Ohio.

[2]Stokes and Smith Company, Philadelphia, Pa.

[3]"Wrapless, Linerless Cartons," Modern Packaging Magazine, August, 1957, p. 92.

A constant stream of adhesive, supplied from a heated reservoir by pump, flows down the roll. All surface adhesive is removed by a heated, spring loaded scraper. The small cavities in the roll retain the adhesive which is transferred simultaneously to the top and bottom flaps of the carton in much the same manner as gravure printing. It must be noted, however, that all machine parts in contact with the adhesive must be heated to prevent coagulation on the parts.

At present, thermoplastic sealed cartons are being used by a producer of frozen foods and the baby cereal division of a pharmaceutical company. It was impossible to obtain technical information on these cartons or procure any samples for testing. The machine company guarantees full fibre tear seal and the ability of the sealed carton to withstand -40 degree temperatures. The carton is a waxed, four flap each end, glued flap type with full length top and bottom flaps. Directions, which are printed directly on the carton, cannot be thrown away by the consumer, as often is the case with overwrapped cartons.

Thermoplastic hot melt sealed cartons of this type, then, are a key to the elimination of overwraps and inner liners and their replacement by functional coatings. Hot melts furnish the method whereby these nearly plastic coatings can be adhered in production.

II. THE WELDING OF THERMOPLASTICS

Introduction

A number of the functional coatings which are being applied to folding boxboard are thermoplastic in themselves, and can be welded or sealed to a similarly coated surface. Therefore, a folding carton coated on both sides with a vinyl copolymer, polyethylene, or similar thermoplastic can be sealed by softening the coating with heat and subsequent cooling under pressure. In order to understand thoroughly how the principle of weldability is applied to folding cartons, it will be necessary to examine the nature of weldable materials and the theory of plastics welding.

The Nature of Weldable Plastics

Plastics fall into the category of amorphous, or noncrystalline substances, as opposed to the other division of solid matter which is crystalline. Crystalline materials demonstrate a regular pattern or geometric arrangement of molecules depending on the degree of stress on the material and the nature of the constituent atoms.

All plastic materials which are used in the coating of folding boxboard are amorphous or noncrystalline. They show little or no organization in their structure, and the atoms lose their individuality in becoming a part of the larger molecular structure.

Because of the random arrangement of molecules, plastic coatings show no definite melting point, but soften gradually with increase in temperature. As the weak bonds between the long chain molecules begin to break down, the material is ready to be sealed or welded to a similarly coated surface.

This heating, which causes softening of the film and allows it to be sealed, can be accomplished by a number of methods. Unsupported plastic films can best be sealed with a jaw type sealer which exerts pressure from both sides simultaneously. In folding carton sealing, however, the product inside the carton prevents the insertion of a mandrel, and the method of folding the flaps flat leaves no lip for the jaws to grip.

Radiant heating can be used for the sealing of folding cartons. The flaps to be sealed must be radiant heated beyond the softening range of the coating, and then closed with the usual pressure and cooling. This method is presently employed by the Pure-Pak Division of Ex-Cell-O Corporation on their experimental polyethylene coated milk carton, which will be examined and tested later in this paper. The equipment used includes a rod type heating element to which the carton is exposed during part of its cycle. With this element held at 1400 degrees F., the coating on the carton is heated over the 250 degrees necessary for softening. The necessary folds are then made while the carton is heated, and a water cooled platen applies pressure until the seal is effected.

Another possible method of heat sealing folding cartons coated with thermoplastic material is through the use of a band sealer. In this method the cartons to be sealed are conveyed between two steel belts to a heating station, where the resin is melted and the seal accomplished. The carton then passes on, still held between the steel belts to a cooling station, after which it is released. This technique virtually eliminates the problem of sticking of the plastic coating to the sealing tool. Since the process is continuous, band sealing would be especially suited to the high speed "assembly-line" filling and sealing mechanisms used in folding carton production. Sealers of the band type require somewhat less attention to temperature and pressure than do other types of heat sealers, due to the extensive length of dwell time involved.

Polyethylene: An Example

The most popular and possibly the most versatile coating which can be heat sealed to itself is polyethylene. In the solid state, polyethylene is a white transluscent, rubbery solid which is applied to its base stock by conventional extrusion coating processes. A film of polyethylene is extruded and applied to the stock under pressure while in a softened state. Adhesion to paper and board is excellent, and very thin coatings can be applied at speeds of 370 feet per minute or higher.

Chemical properties of polyethylene coatings render it an excellent barrier material for folding cartons. It is substantially inert, being unaffected by acids at room temperatures, although softened somewhat by chlorinated hydrocarbons. This, of course, means that acidic foods can be packaged in polyethylene without fear of disintegration of the coating at lower temperatures.

Folding boxboard coated with polyethylene offers physical properties which serve to integrate the protective function of the package into one piece. The coating is free from taste, odor, and toxicity, and resistant to chemicals, solvents, and greases. Its excellent low temperature flexibility permits its use as a coating on frozen food packages or with products intended for arctic use. It does not crack or separate upon folding of the carton blank, and will resist any depth, width, or pressure of scoring rule now used in production.

A property of polyethylene which is especially important in its use as a coating for liquid holding cartons is its excellent resistance to permeation by liquids. The absorption of water by duPont's Alathon 16 is negligible, only 0.01% by standard test.[1] Water vapor permeability depends on the thickness of the coating and the smoothness of the base material, but in most cases is very low. Constructions having coatings as thin as one-half mil (0.0005) are appreciably more resistant to the passage of water than uncoated materials, even those considered reasonably good barriers. Coatings on rough surfaces may not be as effective as on smooth ones, since the coating, in the molten state, will tend to fill in the low spots and barely cover the high ones. Such a coating, greatly magnified, can be visualized in the following figure.

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[1]"Alathon" As a Coating Material, duPont Company, Wilmington, Delaware.

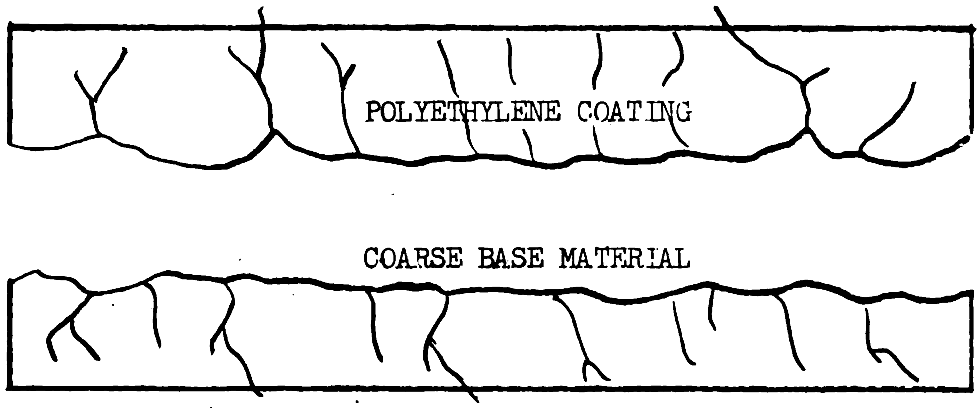


FIGURE 2. Cross section drawing showing the irregular thickness of a thin plastic coating on rough base material.

The protruding fibres act as wicks to transmit grease and moisture.

Finally, polyethylene coatings can be heat sealed, in the temperature range of 250-300 degrees F. Progressively higher sealing temperatures are necessary as the thickness of the base stock increases. Excellent heat seals can be made even when some products deposit dust on the area to be sealed, which might occur in the packaging of dry cereals or meal. Difficulty arises because of the thickness of the paperboard base, but can be reduced by the use of band sealing or radiant heat.

To demonstrate the liquid holding capacity of resin coated cartons, sealing methods used in production, and tests used to evaluate heat sealed cartons, we will examine a paperboard milk carton in the next section. This carton is an experimental design by the Pure-Pak Division of Ex-Cell-O Corporation, and is in limited test production at the Dairy of Michigan State University.

III. EXAMINATION AND TESTING OF HEAT SEALED CARTONS

Introduction

The polyethylene coated heat sealed carton referred to previously demonstrates the liquid holding quality of this type of functionally coated carton. It is presently made in the one quart size, and is in limited production and usage at Michigan State University.

Board stock used in the carton is conventional .019 fourdrinier kraft, 250# per ream, which is also used on the company's popular wax coated milk carton. It is coated with duPont Alathon 34, using a heavier (.0015) coating inside and 3/4 mil or .00075 coating outside. The carton blank (see Figure 3) is prepared by the International Paper Company. The side seam of this carton is sealed using the hot melt method of specific adhesion mentioned earlier in this paper. The adhesive used is prepared in rope form and called "Thermogrip" by the United Shoe Machinery Manufacturing Company, and is applied by automatic machinery. The carton is delivered to the dairy in "knocked down" form.

The machine used in filling and sealing is basically similar to the standard Ex-Cell-O machine presently in use preparing wax coated cartons. The tank of molten paraffin is, of course, omitted, and heating elements which soften the plastic coating and make heat sealing possible are installed.

Suggested Improvements in Carton

Upon examination of the production carton after filling and sealing, a number of possible improvements were observed. First, it was noted that upon folding the gable top of the carton, a delamination occurred in the side seam where it is folded on a reverse score. This delamination causes what is known as a "shoulder leaker" and causes the bottle to be rejected. The delamination occurs in every case, but most do not leak immediately and are, at the time of production, acceptable cartons.

The delamination at this point, however, exposes a greater amount of paper fibre to liquid action which in turn causes further delamination, leading to the development of leaks after a period of time. After experimental scoring and folding of this side seam, it was found that by rotating the seam ninety degrees either way, placing it on a different corner of the carton, the condition could be eliminated. Since the seam would no longer be folded on a reverse score, it would not be subject to as extensive a stress upon folding, and would not tend to delaminate as readily. To accomplish this in production would entail a complete change in both scoring and printing dies. (See Figure 4)

Another area where leaks frequently occurred was on the side opposite the pouring spout, directly under the sealed area. This appeared to be caused by a slight failure in the seal, which was stressed slightly by the tendency of the gable fold to rebound. The only apparent solution was to increase the area of the heat seal, which would impair the easy-opening feature of the pour-spout container. Additional heating of the seal resulted in 85% acceptable cartons, and was considered adequate by technicians of the machine company.

FIGURE 3. Experimental carton blank (Scale: 3/8 = 1).

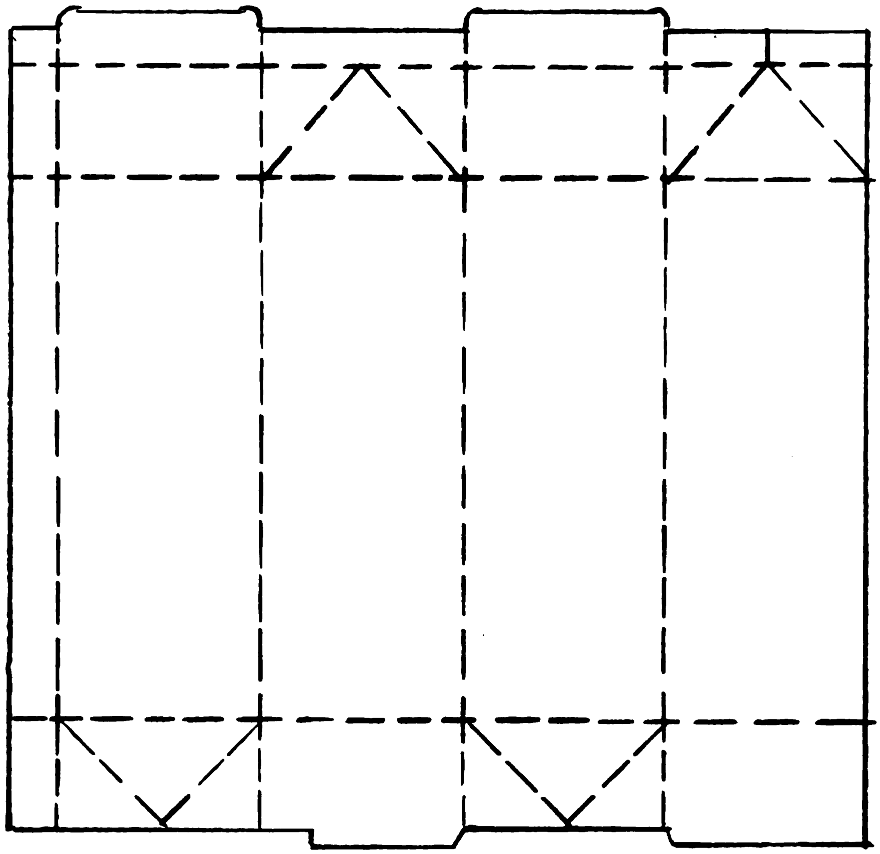
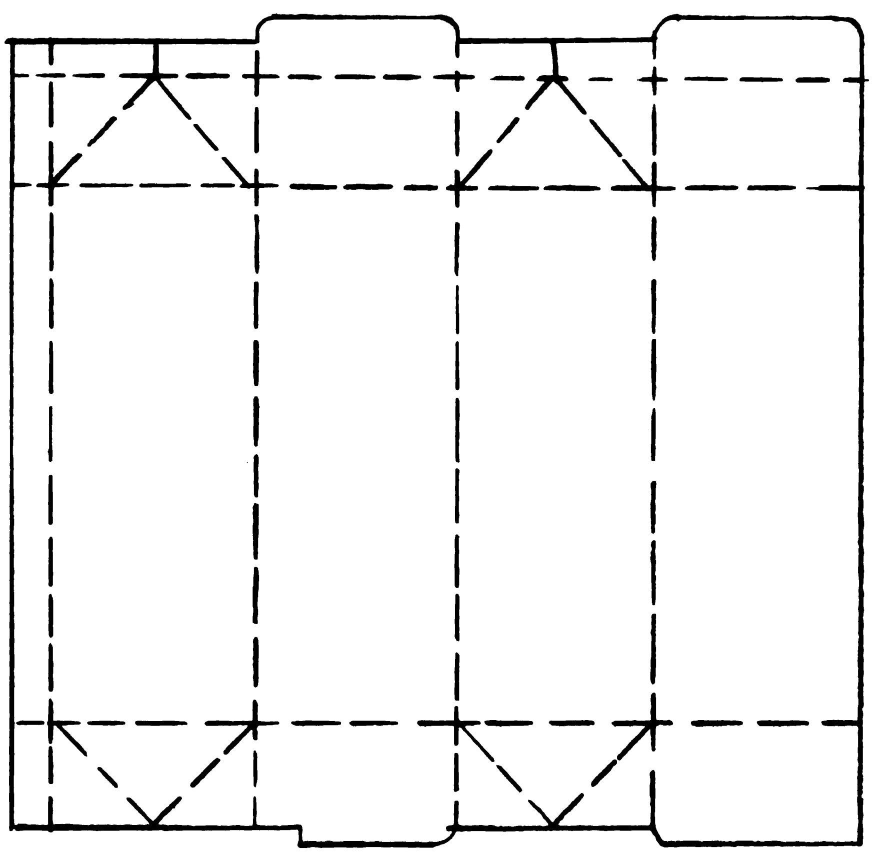


FIGURE 4. Proposed carton blank (Scale: 3/8 = 1).



Choice of Test Methods

In order to arrive at tests which would reflect actual conditions to which milk cartons would be subjected, it was necessary to examine the two basic areas of damage which may occur. First, damage may occur in the commercial handling of the package, during filling, loading into cases, loading in trucks, and in delivery. Since the loading of milk cartons into cases is in most situations by hand, a test of individual cartons would be necessary to reflect possible damage in this area. In all other possible damage situations in commercial handling, the cartons would be loaded in cases of sixteen or twenty and would be supported on all sides by the case and/or adjoining cartons.

The second basic area of possible damage is in consumer handling--the shocks and stresses to which the carton is subject after its delivery to the retail store or to the consumer. Therefore, tests would be necessary which reflect retail store and consumer handling and give realistic results.

Water was used as a filler in all cartons tested in this project. Tests conducted by the Pure-Pak Division showed no significant differences in the wettability of water and milk, and although milk titrates to .01 acid due to proteins and other ingredients, it was felt by the dairy department that water would yield results as reliable as would milk. It would also, of course, be more economical considering the number of filled cartons involved.

Tests of Individual Cartons

In order to reflect the damage which may occur in consumer handling of milk cartons, a standard drop test has been devised by the Pure-Pak Division. It consists of a steel frame which directs the fall of the carton, and a steel damage plate with raised corners which simulates a corner drop on all four corners simultaneously. (See Figure 5) The experimental polyethylene cartons (hereinafter referred to as X poly) were subjected to the drop test in comparison with two types currently in production (hereinafter referred to as Y poly and Y vinyl).

The cartons were divided into three groups, each group containing representative samples of each type of carton. The first group was drop tested immediately after packing and was observed for leaks. The second group was drop tested and observed for leaks after having been stored at standard conditions of 73 degrees and 50% relative humidity for seventy-two hours. It is not likely, however, that milk would be allowed to stand as long as 72 hours under those conditions, but this appeared valuable in determining the type of damage which would occur. The third group of cartons was allowed to stand under standard conditions for a period of 72 hours as a control. These were not drop tested but merely observed at the end of that period for any leaks which may have developed.

A leak, as referred to in these tests, was defined as any appearance of water on the outside of the carton, and usually occurred as a bead of water on or near a seam or fold.

The drop tests were conducted in accordance with the standard procedure as outlined by the Pure-Pak Division in the apparatus pictured in Figure 5. Each carton was dropped ten times from a height of seven inches onto the plate with raised corners. The carton was then placed on a sheet of clay coated chip board which served to indicate the appearance and source of leaks. The time of occurrence and the total number of leaks was recorded. In production of milk cartons, one leak causes rejection, but in this test the number and position of the leaks were recorded in order to discover any weaknesses in the carton. The results of drop testing will be found in the Appendix, Tables I through VI.

It should be noted that the Y poly carton did not withstand the time test. All cartons in the control group and the group to be drop tested after seventy-two hours of this type developed leaks. These leaks did not occur as beads of water appearing at weak points in the carton, but as a thorough wetting of the board on the bottom of the carton. It is believed by the author that this wetting action was due to two factors. First, that the coating of polyethylene on the inside of the carton was not heavy enough to cover the rough surface of the board. Although the lower areas were filled with the molten plastic, the higher regions received little or no coating. Rough fibres penetrating the coating served as wicks which transmitted moisture into the base stock, and eventually wet the material thoroughly. (See Figure 2)

Due to the method used in sealing this particular carton, the outside of the base stock on the bottom was not coated. Since hot irons

FIGURE 5. Standard drop test apparatus, experimental milk carton (l.) and milk carton in present use (r.)

are used for sealing, the coating is omitted to prevent its sticking to the surface of the iron. The irons could be coated with teflon or teflon impregnated cloth which would also prevent sticking and still allow the outer surface of the base stock to be coated with polyethylene.

Therefore, figures are not available on the Y poly carton since leaks were observed in each of them after seventy-two hour storage.

Due to the construction of the cartons tested, each could fail in a total of five possible ways. The standard test submits each corner to pressure similar to a corner drop, and the side seam is also subjected to a stress. Where other types of damage occurred, it will be noted in the Appendix, Table I through VI, where test results are reported.

The following results and relationships were noted from the data recorded in the drop tests:

1. Storage of all cartons for a period of seventy-two hours at standard conditions increased the tendency to leak after drop testing. This is due to the wetting and subsequent weakening of the paper fibres.
2. More leaks of the soaking-through type appeared in cartons stored for seventy-two hours than in those tested immediately after packing. The packages tended to delaminate in the area of the heat seal and allow the water to soak through.
3. Y poly carton did not stand up under storage for seventy-two hours at standard temperature and humidity. The author would recommend that tests be repeated with all cartons under refrigeration.

4. Differences appearing in one type of carton between those tested immediately and those stored for seventy-two hours are greater when observed after twenty-four hours than when observed fifteen minutes after testing. It would appear, then, that time in storage before testing is directly related to the time rate of leakage after testing. (See Tables I, II, IV, and V.)
5. X poly cartons withstood both drop and storage time tests better than did Y poly cartons. X poly also appeared more resistant to leaks after drop testing. (See Appendix, Tables III, IV, and V.)

Tests of Cartons in Cases

In order to reflect the damage which might occur when fibre milk cartons are handled and shipped commercially, it was necessary to utilize tests in which milk cartons loaded in shipping cases could be subjected to adverse conditions. Due to the similar size and weight of loaded milk cases to corrugated shipping cases, two standard test methods were used.

Incline Impact. In many dairies, milk cases are loaded in and unloaded from trucks by the use of an inclined plane on which the cases slide for distances of anywhere from one to ten feet. It was felt that a test was necessary which would subject the cases to similar conditions and would result in damage similar to that suffered in loading and unloading on inclined planes.

The test chosen to accomplish this was the standard incline impact test for shipping containers, ASTM standard D-880-50. The loaded cases were placed on a 10 degree incline, and a slide distance of three and one-half feet was used. The cases were impacted first on the bottom, to simulate a short drop. The next four impacts were on the sides of the case, simulating the shock received by a case sliding on an inclined loader. Each side was impacted once, the case being rotated clockwise ninety degrees after each impact. A sixth impact was then given to the bottom of the case to again simulate a short drop received in loading or unloading the truck.

The cartons were then removed from the case and placed on sheets of clay coated chipboard which served to indicate the occurrence and location of leaks. Each carton was wiped dry with cheesecloth before observation to eliminate the effect of water from other cartons appearing on the surface. Leaking cartons were made apparent by dark spots which appeared on the chipboard. The number of leaking cartons per case was recorded and will be found in the Appendix, Tables VII and VIII. Both wire and aluminum cases were used, and are pictured in Figures 6 and 7. Before attempting to interpret the results of the incline impact tests, the following considerations must be noted:

1. That variations occurred from day to day in identical tests. This could be attributed to—

    a) variations in sampling from production runs, or

    b) variations in atmospheric conditions which would tend to cause differences in carton moisture content and temperature.

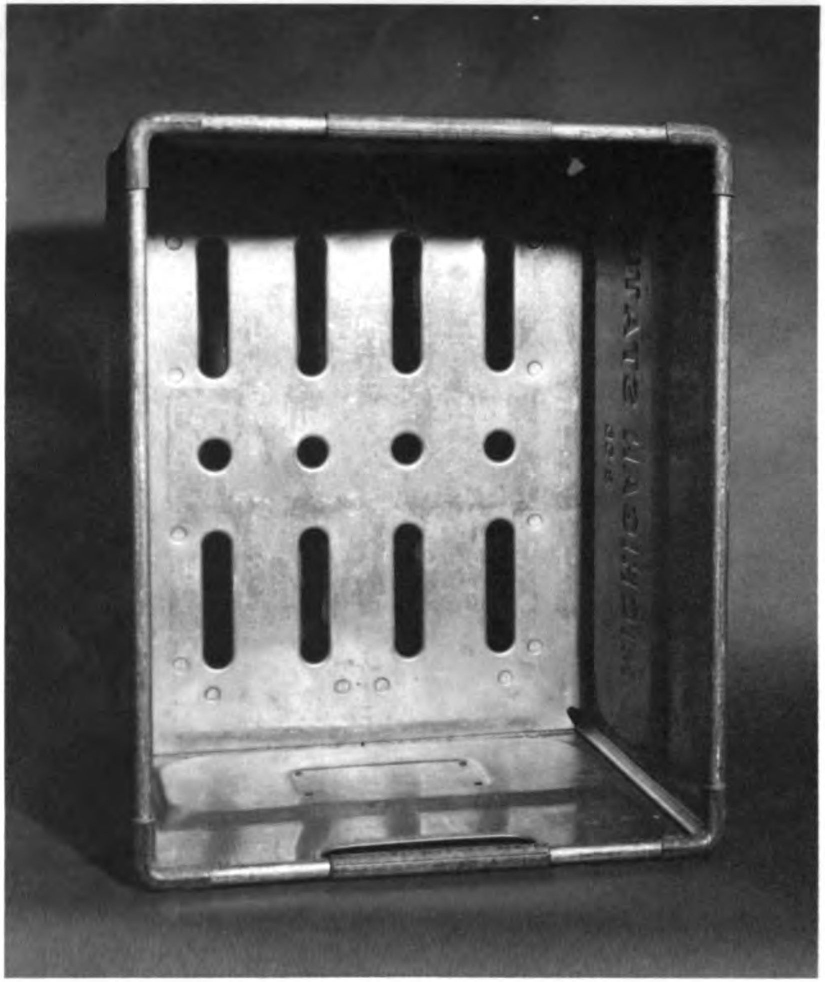


FIGURE 6. Michigan State University aluminum case in which milk cartons were tested

FIGURE 7. Michigan State University wire case in which milk cartons were tested

2. That a limited sampling was available and could not be analyzed statistically with any degree of accuracy. The tests made possible the observation of relative ability to withstand adverse conditions, and of points of weakness in the carton, rather than a statistical analysis of damage and variance.

Conclusions, based on the results of impact testing, are as follows:

1. The most apparent weakness in both X poly and X wax cartons upon impact was the opening of the top seal. The impact perpendicular to the line of the gable tended to pull out the staple in the wax carton and to delaminate the board in the seal area of the poly carton. Leaks of this nature are noted in the Appendix, Tables VII and VIII.
2. In no case did the side seam weaken or break as was expected under this type of test. The support of other cartons within the case apparently prevented this.
3. Reaction of identical cartons to different type of cases in this test caused different results. The raw edges of the wire case tended to chafe and puncture the cartons, causing the damage in this type of case to be more extensive.
4. Storage time of seventy-two hours caused weakening of the cartons which resulted in a greater number of leaks appearing after testing.

Flat Table Vibration Tests

Much damage can be done to the bottoms of fibreboard milk cartons by the vibration and bouncing action caused by the delivery truck. This causes friction on the sides of the carton and frequent short drops on the bottom of the case. In order to simulate this bounce and vibration, samples of X poly and X wax cartons were subjected to the standard vibration test, ASTM standard D-999-48T.

In the first part of the test, cartons of the X poly and X wax types were packed and conditioned for twenty-four hours under refrigeration at forty degrees F. Samples were packed in both aluminum and wire cases, diagrams and descriptions of which shall be found in Figure 6. The sample cases were placed on a vibrating table driven by eccentrics which give it a circular harmonic vibratory motion in a vertical plane. Procedure "A" was followed, with the cases placed on the table without fastening.[1]

The table was operated at a speed which resulted in forces equivalent to one times gravity acting on the case, with a vertical distance of one inch. The test was continued for two minutes. Detailed records of the test on each case, including type of damage to containers and number of cartons which leaked, as well as other observations, will be found in the Appendix, Tables IX and X.

Conclusions based on test results and observations are as follows:

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[1]American Society for Testing Materials, Standards on Paper and Paper Products and Shipping Containers.

1. Size of the case in which milk cartons are delivered is a primary consideration in the resistance of the carton to vibration in a vertical plane. The standard Michigan State University aluminum case, which is slightly larger than the standard Michigan State University wire case, gave vibration test results of considerably more damage. The cartons tended to bounce within the case instead of "staying with it," and hence more damage was caused to the bottoms. It was also observed that the printing on the sides of the carton was obliterated on the polyethylene cartons which were tested in aluminum cases due to excessive motion within the case.
2. Cartons stored for seventy-two hours under forty degree refrigeration showed less tendency to bounce and leak than those tested twenty-four hours after packing. The tendency of the carton to bulge and conform to the dimensions of the case over a period of time resulted in less damage as a result of vibration testing.

Heat Transfer Tests

A customer acceptance survey was conducted by the Dairy Department of Michigan State University concerning the user's reaction to the experimental polyethylene coated milk carton. Consumer acceptance was unanimous in such areas as looks, feel, "in the refrigerator" and "on the table,"[1] but a significant number complained that the new

[1]From Consumer Acceptance Questionnaire, Michigan State University Dairy Department.

carton did not "keep the milk as cold" as the standard wax coated carton.

The hypothesis was then made that the polyethylene coating, being a better insulator than wax, would prevent the milk from reaching the refrigerator temperature at as fast a rate as would the milk in the wax carton. The manifestations of this condition would be: a) that upon removal from the refrigerator and remaining open for a length of time, the temperature of the milk in each carton would raise at the same rate, and b) that upon reclosure and replacement in the refrigerator, the milk in the wax carton would return to the refrigerator temperature at a faster rate. If removed before a certain length of time, then, the milk in the polyethylene carton would be warmer than that in the wax.

In order to examine this hypothesis, a test was devised in which the heat transfer rate was measured and recorded for each type of carton. Two sets of cartons of each type were used for the heat transfer tests.

The first group of cartons, ten wax coated and ten polyethylene coated, were refrigerated for twenty-four hours after packing at a temperature of forty degrees F. They were then removed to the conditioning room of the packaging Laboratory under conditions of seventy-three degrees F. and fifty percent relative humidity.

The second group of cartons, ten wax and ten heat sealed polyethylene, were stored at standard conditions of seventy-three degrees F. and fifty percent relative humidity for a period of twenty-four hours. They were then removed to refrigerated conditions of forty-three degrees F.

The temperature change was measured every hour and was recorded. The data sheets are reproduced in Tables XI through XIV in the Appendix. In Tables XV and XVI the temperature change is plotted as a function of time and the differences are more clearly represented.

Results of the tests are as follows:

1. Milk in wax coated cartons increases in temperature at a faster rate than milk in polyethylene coated cartons. This rate decreases with time, as can be seen in Table XVI in the Appendix.
2. Milk in wax coated cartons decreases in temperature at a slightly faster rate for approximately two and one-half hours, then decreases more slowly than milk in polyethylene coated cartons. (See Appendix, Table XV.)

Conclusions:

1. Polyethylene cartons serve as better insulators for milk and tend to resist temperature change more than wax cartons.
2. A wax carton under refrigeration for less than two and one-half hours after having been exposed to higher temperature will give lower temperature readings than a polyethylene coated carton under the same conditions. The milk, therefore, in the wax carton would be colder than that in the plastic carton up to two and one-half hours after refrigeration.

IV. CONCLUSIONS

One piece heat sealed folding cartons have advantages to both consumer and the producer. In their present form they also have disadvantages which must be resolved before universal acceptance is feasable.

First, one piece cartons which are functionally coated are extremely difficult to seal, and the packager must rely on either expensive hot melts or equally expensive thermoplastic coatings which can be sealed. Either method leaves room for improvement which can be brought about by testing and research. Adhesive producers, carton manufacturers, and machinery producers can aid in the solution of these problems by cooperation with universities such as Michigan State who show an interest in packaging as a true science.

It is imperative, however, that cooperation between industry and the university in the interests of packaging as a science be placed before the selfish interests of the individual concern. Research cannot take place at the university level without this cooperation, and duplication of work due to poor communications must be prevented at all costs.

Since only two hot melt sealed folding cartons are presently being produced commercially, the potential for gathering information in this area is large. However, it was found to be exceedingly difficult to obtain technical information concerning the production or sealing of these cartons. It was equally difficult, in fact impossible, to obtain sample cartons, either sealed, unsealed, or in flat blank form.

It is recommended that as soon as materials and technical information become available in the area of hot melt sealed one piece folding cartons, tests for siftproofness be devised. This feature would be essential in a one piece carton used for powdered or dry products, and although the producers of the frozen food carton mentioned earlier claim siftproofness of cartons, they show no data or test methods with which to uphold this claim. They also declined to furnish sample cartons for testing by the author using proposed methods.

It was originally planned to include in this project the development of two tests--one for siftproofness and one for mechanical tightness--and to attempt to correlate the two. The proposed tests will be outlined herein in the hope that as materials and information become available they can be examined.

Proposed Test for Siftproofness

One piece heat sealed folding cartons shall be filled with uniformly fine sand which has been oven dried. The weight of each carton shall be measured accurately to the nearest .01 pound. These cartons shall be confined in an apparatus which will rotate the carton around its center axis in circular harmonic motion for a designated period of time. At the end of this period the carton shall be removed from the apparatus and again weighed accurately. The weight loss of each carton will then give an indication of its siftproofness.

It is suggested that the apparatus frequently used in retail stores for mixing paint gives the type of motion which would put maximum pressure of the carton contents on the sealed areas.

Proposed Test for Mechanical Tightness

One piece cartons shall be heat sealed with no material being placed inside. Each test carton shall be placed flat between the platens of a press which will measure accurately any change in pressure exerted against the upper platen. It is suggested that a Baldwin-Emery or similar testing machine which can be equipped with a sensitive load cell be used. Each carton to be tested shall be fitted with a rubber diaphragm on the narrow side, which will allow the insertion of a hypodermic needle into the carton without allowing the escape of air. Air will then be introduced into the carton through the needle until a predetermined pressure is reached. The escape of air from within the carton shall be timed accurately as the pressure reduces from the predetermined point to zero.

Mechanical tightness can then be reported in terms of the time rate of air escape through the sealed areas of the carton. It may be necessary to measure first the porosity of the material used in the carton to be tested, and to allow for the effect of air escape through the walls of the carton.

An attempt should then be made to study any correlation of mechanical tightness with siftproofness, in order to prevent duplication of information. It is possible that the two tests may, in effect, measure the same thing.

Conclusions on Tests

Cartons continuously coated with thermoplastic materials can be heat sealed by the softening of the coating, welding by pressure, and subsequent cooling. Tests conducted on experimental milk cartons of this type showed that the integrity of the seal is as great as that of adhesive sealed cartons. The experimental carton stands up well under adverse conditions. and is an acceptable package according to consumer surveys.

In individual drop tests, it proved a better liquid holding carton than types presently in production. In impact and vibration tests, it proved equal in ability to withstand stress, and similar in types of damage suffered.

The advantages of faster production speeds, one piece construction, and ease of sealing will eventually bring heat sealed folding cartons to the fore as the most popular with both consumers and producers of packaged products.

APPENDIX

TABLE I

DROP TEST RESULTS

CARTONS COATED WITH VINYL COPOLYMER—IMMEDIATELY AFTER PACKING

Sample	15 Min.	1 Hour	24 Hours	Remarks
1	0	1	1	corner leak
2	1	1	1	corner leak
3	0	1	1	corner leak
4	2	2	2	corner leak
5	2	2	4	beads of water appearing on bottom edge
6	1	1	1	corner leaks
7	3	3	4	beads of water on bottom edge
8	2	2	2	corner leak
9	1	1	2	corner leak
10	3	3	4	delamination in seal area
11	1	1	1	corner leaks
12	2	2	4	beads of water on bottom edge
Total	18	20	28	
Mean	1.5	1.66	2.33	

TABLE II

DROP TEST RESULTS

CARTONS COATED WITH VINYL COPOLYMER—AFTER 72 HOUR STORAGE

Sample	15 Min.	1 Hour	24 Hours	Remarks
1	1	1	3	all corner leaks
2	2	3	3	all corner leaks
3	0	0	1	corner leak
4	2	2	4	all corner leaks
5	1	1	5	small beads on bottom edge*
6	1	1	4	small beads on bottom edge
7	3	3	4	delamination in area of seal
8	1	1	2	corner leak
9	2	2	3	small beads on bottom edge
10	3	3	4	small beads on bottom edge
11	3	3	4	small beads on bottom edge
12	2	2	2	small beads on bottom edge
Total	21	22	39	
Mean	1.75	1.83	3.25	

*Appearance of small beads on bottom edge denotes a soaking through effect.

TABLE III

DROP TEST RESULTS

CARTONS COATED WITH POLYETHYLENE (Y POLY)--IMMEDIATELY AFTER PACKING

Sample	15 Min.	1 Hour	24 Hours	Remarks
1	3	3	5	four corner leaks, on bottom edge bead
2	2	3	4	all corner leaks
3	2	2	3	corner leaks
4	2	2	4	corner leaks
5	2	2	3	corner leaks
6	0	1	1	soaking effect near side seam
7	2	2	3	corner leaks
8	1	1	4	corner leaks, beads on edge
9	3	3	3	corner leaks
10	2	2	4	corner leaks
11	2	2	3	corner leaks
12	1	1	3	corner leaks
Total	22	24	40	
Mean	1.83	2.00	3.34	

TABLE IV

DROP TEST RESULTS

CARTONS COATED WITH POLYETHYLENE (X POLY)—IMMEDIATELY AFTER PACKING

Sample	15 Min.	1 Hour	24 Hours	Remarks
1	0	0	1	leak in side seam corner
2	0	0	0	
3	0	0	0	
4	0	0	0	
5	0	0	1	failure of bottom seal
6	0	0	0	
7	0	0	0	
8	0	0	0	
9	0	0	0	
10	1	1	2	failure of bottom seal
11	0	0	0	
12	0	0	0	
Total	1	1	4	
Mean	.08	.08	.33	

TABLE V

DROP TEST RESULTS

CARTONS COATED WITH POLYETHYLENE (X POLY)--AFTER 72 HOUR STORAGE

Sample	15 Min.	1 Hour	24 Hours	Remarks
1	0	0	1	side seam corner
2	1	1	2	failure of bottom seal at side
3	0	0	0	
4	0	0	1	failure of bottom seal at side
5	0	1	2	failure of bottom seal at side
6	0	0	0	
7	0	1	2	side seam corner, bottom seal
8	0	0	0	
9	1	1	1	side seam corner
10	0	0	0	
11	0	0	1	failure of bottom seal
12	0	0	0	
Total	2	4	9	
Mean	.166	.33	.75	

TABLE VI

CONTROL GROUP

STORED FOR 72 HOURS, NOT DROP TESTED

Sample	Remarks
1. Y Vinyl carton	no leaks observed after atorage
2. Y Poly carton	all cartons leaked after storage
3. X Poly carton	no leaks observed after storage

TABLE VII

IMPACT TEST RESULTS

ASTM STANDARD D880-50

POLYETHYLENE COATED CARTONS (X POLY)

			Remarks
Wire Case			
24 hours	20	9	delamination of top seal
72 hours	20	3	delamination of top seal
Aluminum Case			
24 hours	20	10	delamination of top seal
72 hours	20	10	delamination of top seal

TABLE VIII

IMPACT TEST RESULTS

ASTM STANDARD D880-50

WAX COATED CARTONS (X WAX)

			Remarks
Wire Case			
24 hours	20	17	staple pulled out at top
72 hours	20	15	staple pulled out at top
Aluminum Case			
24 hours	20	14	staple pulled out at top
72 hours	20	13	staple pulled out at top

TABLE IX

VIBRATION TEST RESULTS

ASTM STANDARD D999-48T

POLYETHYLENE COATED CARTONS (X POLY)

			Remarks
Wire Case			
24 hours	20	5	leaks in bottom seal
72 hours	40	9	leaks in bottom seal
Aluminum Case			
24 hours	20	0	
72 hours	40	0	

TABLE X

VIBRATION TEST RESULTS

ASTM STANDARD D999-48T

WAX COATED CARTONS (X WAX)

			Remarks
Wire Case			
24 hours	20	6	failure of bottom corners
72 hours	20	1	top side seam failure
Aluminum Case			
24 hours	20	3	wax failure on bottom seam
72 hours	20	0	

TABLE XI

HEAT TRANSFER TEST RESULTS

X WAX CARTONS—MEASUREMENT OF TEMPERATURE DECREASE

Sample	Initial Temp.	Diff.	1 Hr.	Diff.	2 Hrs	Diff.	3 Hrs	Diff.	4 Hrs	Diff.	5 Hrs	Diff.	6 Hrs	Total Time	Total Change	Rate /Hr.
1	68	8	60	5.5	54.5	3.5	51	1.5	49.5	1.5	48.0	1.0	47.0	6	21	3.24
2	68	10	58	4.5	53.5	3.5	50	2.0	48.0	1.0	47.0	1.0	46.0	6	22	3.39
3	68	8	60	5.0	55.0	3.0	52	2.0	50.0	2.0	48.0	1.0	47.0	6	21	3.24
4	68	9	59	5.0	54.0	4.0	50	1.5	48.5	1.5	47.0	1.0	46.0	6	22	3.39
5	68	8	60	5.0	55.0	4.5	50.5	1.5	49.0	1.0	48.0	1.5	46.5	6	21.5	3.31
6	68	9	59	5.0	54.0	4.5	41.5	1.0	48.5	1.5	47.0	1.0	46.0	6	22.0	3.39
7	68	10	58	3.5	54.5	4.0	50.5	1.5	49.0	1.0	48.0	1.5	46.5	6	21.5	3.31
8	68	10	58	4.5	53.5	3.5	50.0	2.0	48.0	1.0	47.0	1.5	45.5	6	22.5	3.46
9	68	10	58	4.0	54.0	4.0	50.0	1.0	49.0	1.5	47.5	1.5	46.0	6	22	3.39
10	68	9	59	5.5	53.5	3.5	50.0	2.0	48.0	1.5	46.5	1.0	45.5	6	21.5	3.31
$\bar{X}$	68	9.1	58.9	4.75	54.1	3.8	50.3	1.6	48.7	1.3	47.4	1.2	46.2	6	21.7	3.34

TABLE XII

HEAT TRANSFER TEST RESULTS

X POLY CARTONS—MEASUREMENT OF TEMPERATURE DECREASE

Sample	Initial Temp.	Diff.	1 Hr.	Diff.	2 Hrs	Diff.	3 Hrs	Diff.	4 Hrs	Diff.	5 Hrs	Diff.	6 Hrs	Total Time	Total Change	Rate /Hr.
1	68	7.0	61.0	6.0	55.0	4.0	51.0	2.5	48.5	1.5	47.0	1.0	46.0	6	22.0	3.39
2	68	7.0	61.0	6.0	55.0	5.0	50.0	2.0	48.0	1.5	46.5	1.5	45.0	6	23.0	3.54
3	68	7.0	61.0	6.0	55.0	4.5	50.5	1.5	49.0	1.5	47.5	1.5	46.0	6	22.0	3.39
4	68	8.0	60.0	5.5	54.5	4.5	50.0	2.0	48.0	1.0	47.0	1.0	46.0	6	22.0	3.39
5	68	8.0	60.0	5.0	55.0	4.5	50.5	1.5	49.0	1.5	47.5	1.5	46.0	6	22.0	3.39
6	68	8.0	60.0	5.0	55.0	5.0	50.0	2.0	48.0	1.5	46.5	1.0	45.5	6	22.5	3.46
7	68	8.0	60.0	5.0	55.0	5.5	49.5	0.5	49.0	1.5	47.5	1.5	46.0	6	22.0	3.39
8	68	8.0	60.0	5.5	54.5	4.5	50.0	2.0	48.0	1.5	46.5	1.5	45.0	6	23.0	3.54
9	68	8.5	59.5	5.5	54.0	4.0	50.0	1.0	49.0	1.0	48.0	1.5	46.5	6	21.5	3.31
10	68	9.0	59.0	5.5	53.5	2.5	51.0	3.0	48.0	1.0	47.0	1.5	45.5	6	22.5	3.46
$\bar{X}$	68	7.9	60.1	5.4	54.6	4.3	50.3	1.9	48.4	1.3	47.1	1.3	45.8	6	22.2	3.42

TABLE XII

HEAT TRANSFER TEST RESULTS

X POLY CARTONS—MEASUREMENT OF TEMPERATURE DECREASE

Sample	Initial Temp.	Diff.	1 Hr.	Diff.	2 Hrs	Diff.	3 Hrs	Diff.	4 Hrs	Diff.	5 Hrs	Diff.	6 Hrs	Total Time	Total Change	Rate /Hr.
1	68	7.0	61.0	6.0	55.0	4.0	51.0	2.5	48.5	1.5	47.0	1.0	46.0	6	22.0	3.39
2	68	7.0	61.0	6.0	55.0	5.0	50.0	2.0	48.0	1.5	46.5	1.5	45.0	6	23.0	3.54
3	68	7.0	61.0	6.0	55.0	4.5	50.5	1.5	49.0	1.5	47.5	1.5	46.0	6	22.0	3.39
4	68	8.0	60.0	5.5	54.5	4.5	50.0	2.0	48.0	1.0	47.0	1.0	46.0	6	22.0	3.39
5	68	8.0	60.0	5.0	55.0	4.5	50.5	1.5	49.0	1.5	47.5	1.5	46.0	6	22.0	3.39
6	68	8.0	60.0	5.0	55.0	5.0	50.0	2.0	48.0	1.5	46.5	1.0	45.5	6	22.5	3.46
7	68	8.0	60.0	5.0	55.0	5.5	49.5	0.5	49.0	1.5	47.5	1.5	46.0	6	22.0	3.39
8	68	8.0	60.0	5.5	54.5	4.5	50.0	2.0	48.0	1.5	46.5	1.5	45.0	6	23.0	3.54
9	68	8.5	59.5	5.5	54.0	4.0	50.0	1.0	49.0	1.0	48.0	1.5	46.5	6	21.5	3.31
10	68	9.0	59.0	5.5	53.5	2.5	51.0	3.0	48.0	1.0	47.0	1.5	45.5	6	22.5	3.46
$\bar{X}$	68	7.9	60.1	5.4	54.6	4.3	50.3	1.9	48.4	1.3	47.1	1.3	45.8	6	22.2	3.42

TABLE XIII

HEAT TRANSFER TEST RESULTS

X WAX CARTONS—MEASUREMENT OF TEMPERATURE INCREASE

Sample	Initial Temp.	Diff.	1 Hr.	Diff.	2 Hrs	Diff.	3 Hrs	Diff.	4 Hrs	Diff.	5 Hrs	Diff.	6 Hrs	Total Time	Total Change	Rate /Hr.
1	38	8.5	46.5	11.5			58.0	3.0	61.0	4.5	65.5	2.5	68.0	6	30.0	5.00
2	38	8.0	46.0	10.0			56.0	5.0	61.0	3.5	64.5	2.0	66.5	6	28.5	4.75
3	38	10.0	48.0	10.0			58.0	5.0	63.0	3.0	66.0	2.0	68.0	6	30.0	5.00
4	38	8.0	46.0	10.0			56.0	4.0	60.0	4.0	64.0	2.0	66.0	6	28.0	4.66
5	38	10.0	48.0	10.0			58.0	2.0	60.0	4.0	64.0	2.0	66.0	6	28.0	4.66
6	38	10.0	48.0	9.0			57.0	5.0	62.0	1.0	63.0	2.5	65.5	6	27.5	4.54
7	38	9.0	47.0	12.0			59.0	2.0	61.0	4.0	65.0	2.0	67.0	6	29.0	4.84
8	38	9.5	47.5	9.5			58.0	4.0	62.0	4.0	66.0	1.5	67.5	6	29.5	4.92
9	38	9.0	47.0	10.0			57.0	3.0	60.0	4.0	64.0	2.0	66.0	6	28.0	4.66
10	38	10.0	48.0	10.0			50.0	2.0	60.0	3.5	63.0	2.5	66.0	6	28.0	4.66
$\bar{X}$	38	9.2	47.2	10.2			57.5	3.6	61.0	3.55	64.5	2.3	66.6	6	28.5	4.75

TABLE XIV

HEAT TRANSFER TEST RESULTS

X POLY CARTONS—MEASUREMENT OF TEMPERATURE INCREASE

Sample	Initial Temp.	Diff.	1 Hr.	Diff.	2 Hrs	Diff.	3 Hrs	Diff.	4 Hrs	Diff.	5 Hrs	Diff.	6 Hrs	Total Time	Total Change	Rate /Hr.
1	38	6.0	44.0	10.0			54.0	6.0	60.0	3.5	63.5	2.5	66.0	6	28.0	4.66
2	38	7.0	45.0	9.0			54.0	6.0	60.0	3.0	63.0	2.0	65.0	6	27.0	4.50
3	38	5.0	43.0	12.0			55.0	5.0	60.0	4.0	64.0	2.0	66.0	6	28.0	4.66
4	38	6.0	44.0	10.0			54.0	6.0	60.0	3.5	63.5	2.5	66.0	6	28.0	4.66
5	38	8.0	46.0	9.0			55.0	5.0	60.0	4.0	64.0	2.0	66.0	6	28.0	4.66
6	38	10.0	48.0	9.0			57.0	5.0	62.0	3.0	65.0	2.5	67.5	6	29.5	4.92
7	38	4.0	42.0	14.0			56.0	4.0	60.0	4.5	64.5	1.5	66.0	6	28.0	4.66
8	38	9.0	47.0	10.0			57.0	4.5	61.5	3.5	65.0	2.0	67.0	6	29.0	4.84
9	38	4.0	42.0	14.0			56.0	5.5	61.5	4.0	65.5	2.0	67.5	6	29.5	4.92
10	38	4.0	42.0	14.0			56.0	5.0	61.0	4.0	65.0	2.0	67.0	6	29.0	4.84
$\bar{X}$	38	6.3	44.3	10.1			55.4	5.2	60.6	3.7	64.3	2.1	66.4	6	28.4	4.74

TABLE XV

TEMPERATURE DECREASE AS A FUNCTION OF TIME POLYETHYLENE AND WAX CARTONS

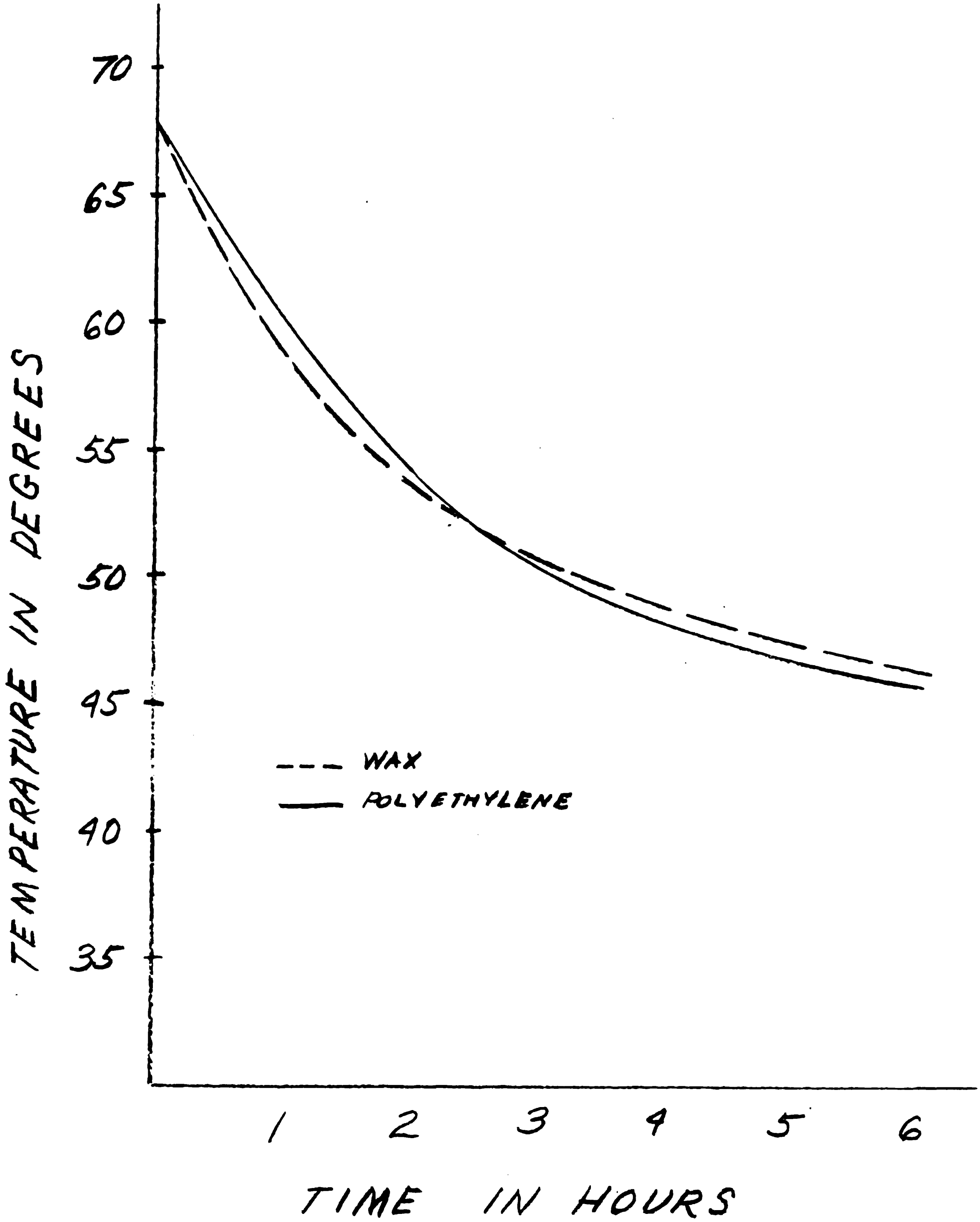


TABLE XVI

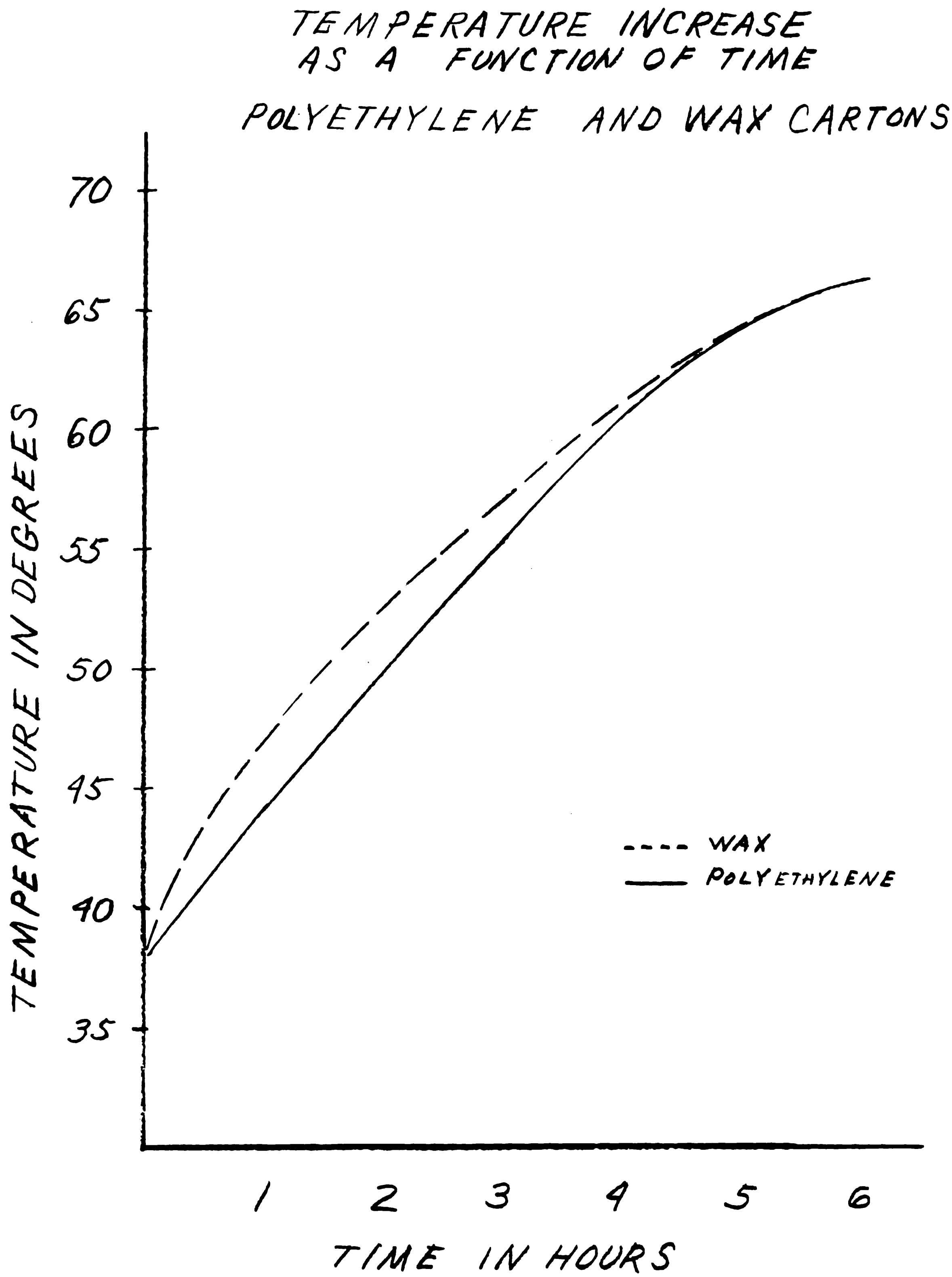
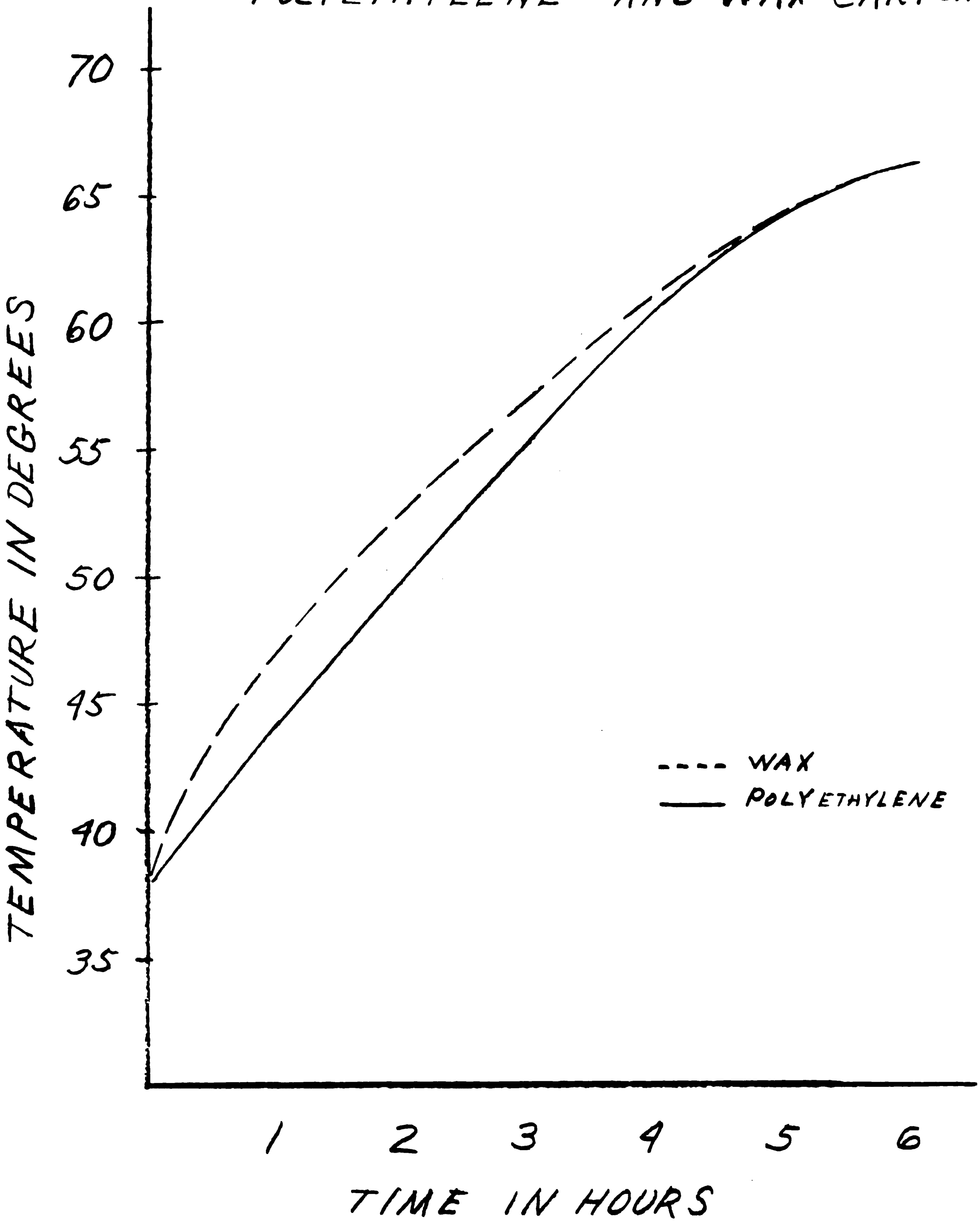

TEMPERATURE INCREASE
AS A FUNCTION OF TIME
POLYETHYLENE AND WAX CARTONS
70
65
60
55
50
45
40
35
TEMPERATURE IN DEGREES
WAX
POLYETHYLENE
1
2
3
4
5
6
TIME IN HOURS

TABLE XVI

TEMPERATURE INCREASE
AS A FUNCTION OF TIME

POLYETHYLENE AND WAX CARTONS



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