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MEASURING THE SORPTION AND DIFFUSION OF WATER IN A MOISTURE SENSITIVE PRODUCT FOR USE IN SHELF LIFE SIMULATION

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MEASURING THE SORPTION AND DIFFUSION OF WATER IN A MOISTURE SENSITIVE PRODUCT FOR USE IN SHELF LIFE SIMULATION

By

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ABSTRACT

MEASURING THE SORPTION AND DIFFUSION OF WATER IN A MOISTURE SENSITIVE PRODUCT FOR USE IN SHELF LIFE SIMULATION

By

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A validation of a finite difference method computer program for estimating the shelf life of a packaged moisture sensitive pharmaceutical tablet is described. The parameters required to execute this computer model include the diffusion coefficient of the pharmaceutical product and the diffusion coefficient of the blister packaging material with respect to water vapor, as well as the solubility of water vapor in the packaging material. All of these parameters were determined experimentally using a Cahn electrobalance at various relative humidity values at 25.0 degrees Celsius.

In addition, the entire blister package / tablet system was monitored at two upper humidity levels for moisture gain as a function of time.

The GAB (Guggenheim-Anderson-de Boer) equation was used to fit the experimental moisture sorption isotherm data generated for the tablet.

A finite difference method computer program was found to be very helpful for predicting the shelf life of a moisture sensitive product, if all of the key physical characteristics of the product and packaging material are known.

Dedicated to my grandmother, Marguerite Allen, who gave me the inspiration to achieve my goals.

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LIST OF SYMBOLS

A	Surface area
A_w	Water activity
A.H.	Absolute humidity
a	Weight of filled blister package at time (t)
b_1	Statistical parameter for isotherm description
b_2	Statistical parameter for isotherm description
b	Weight of empty blister package at time (t)
C	Guggenheim constant
CMC	Critical Moisture Content
c_{sat}	Water concentration in air at saturation
D	Diffusion coefficient
D_L	Package diffusion coefficient
D_R	Tablet diffusion coefficient
dw	Weight of water transferred across film
$d\theta$	Change in time
EMC	Equilibrium Moisture Content
Exp.	Experimental
GAB	Guggenheim-Anderson-de Boer
H_L	Henry's Law Constant
H_m	Total heat of sorption of first layer on primary sites
H_q	Total heat of sorption of multilayers
H_1	Heat of condensation of pure water vapor
IMC	Initial Moisture Content
k	Factor or slope
L,l	Average plastic film or product thickness
M_t	Tablet weight gain at time (t)
M_∞	Final tablet weight gain
M.C.	Moisture content
N	Number of experimental data points in isotherm
P	Permeability
p_i	Water vapor pressure outside film
p_o	Water vapor pressure inside film
PVC	Polyvinyl chloride
p	Water vapor pressure of product
P_T	Laminate permeability
R_p	Blister radius
R_T	Tablet radius
R.H.	Relative humidity
r	radius
RMS	Root mean square
S	Solubility coefficient
T	Temperature

t	Time
$t_{1/2}$	Half time to reach steady state
U	Number of shells for tablet
V_p	Blister volume
V_T	Tablet volume
W	Water content on dry basis
W_f	Final equilibrium tablet weight
W_i	Initial tablet weight
W_i^*	Calculated water content
W_m	Water content corresponding to saturation of adsorption sites
W_t	Tablet weight at time (t)
WVTR	Water Vapor Transmission Rate
ΔW	Weight change
X	Summation of experimental A_w
X_M	Monolayer moisture content
Y	Summation of experimental A_w/EMC
θ	Time lag
α	GAB constant
β	GAB constant
γ	GAB constant

INTRODUCTION

In the pharmaceutical industry, a major concern lies in the determination of the necessary packaging materials to prevent moisture and other environmental factors from adversely affecting a product throughout its shelf life. The Food and Drug Administration requires extensive data supporting the choice of packaging a pharmaceutical product in a given packaging component. It would be very beneficial to have this information as early as possible, so that package design could be implemented based on actual realistic data as opposed to assumptions. In response to this need, several types of computer programs have been written to act as a simulation of the shelf life under certain conditions.

Many of these shelf life models consider different aspects of the product and package. One program in particular uses a finite difference method to compute the shelf life of a moisture sensitive product. This mathematical model requires knowledge of the diffusion properties of both the product and the packaging film. In addition, it takes into account the solubility of water vapor in the package system. This project involves experimental validation of a finite difference method. The objectives of this study are identified below:

A. To observe the sorption characteristics of a moisture sensitive pharmaceutical tablet and blister packaging material experimentally.

B. To calculate the diffusion coefficient of water vapor for both the product and package material.

C. To determine the moisture gain of the complete package/ product system at specific relative humidity levels and validate the calculated shelf life of the package.

D. To apply all of the acquired data to a finite difference computer model in order to generate the shelf life of the tablet.

E. To compare the experimental and simulated moisture gain profile to validate the simulation model based on a finite difference method.

LITERATURE REVIEW

Shelf Life of Moisture Sensitive Products

A very critical parameter in the selection of packaging for the food and pharmaceutical industries is the ability to obtain the proper shelf life needed for a product. Shelf life may be defined as the amount of time that a package or the product in the container will remain in a saleable or acceptable condition under specific storage conditions (Harte and Gray, 1987). Product shelf life can be altered by modifying its composition and form, the environment to which it is exposed, or the packaging system. The shelf life can be affected by environmental conditions, such as temperature and relative humidity. Therefore, it becomes necessary to have methods for predicting the shelf life based on product characteristics, external environment, and type of barrier packaging material utilized. In the case of moisture sensitive products, predictions for the end of shelf life, due to a gain of a critical amount of moisture, can be made if the temperature and relative humidity conditions are known as a function of time, and the package permeability to moisture is also known (Labuza, 1982).

It can be concluded that one of the primary environmental factors that result in increased loss of quality and nutrition for most products is exposure to increased temperature (Labuza, 1982). In addition, gain of moisture by dry or semi-dry substances can lead to several modes of deterioration, such as microbial growth, softness, hardening, and caking.

The current FDA guidelines for documentation of acceptable packaging for human drugs and biologics require 3 years of shelf life data based on 2 kinetic concepts, one of which is reaction and the other is migration (Kim and Gilbert, 1989).

Where solid dosage forms are concerned, moisture plays a very significant role in preformulation testing. Preformulation testing can be defined as an investigation of the physical and chemical properties of a drug substance - alone and in combination with excipients. The ultimate objective of preformulation testing is to gather information useful to the formulator in the development of stable and bioavailable dosage forms which can be mass-produced (Schepky and Thomae, 1989). These sorption studies are designed to show quantitative relationships between the product samples and moisture. It is often possible to ensure that a final formulation exhibits the desired sorption properties by careful selection of the excipients.

If a container is empty, water vapor will pass through the container wall until the relative humidity inside the container is equal to the ambient atmosphere. In a drug-filled container, the difference in internal and external relative humidity impels moisture to become introduced to the inside of the package and some amount of it will be absorbed by the product. The drug absorbs water in a predictable fashion, following its water absorption properties (Bonis, 1989). The package contents act as a moisture sink and retards equilibrium. When the product moisture content has reached an equilibrium with the ambient relative humidity, the humidities inside and outside the container are equal, therefore reducing the driving force to zero.

Moisture Sorption Isotherm

In order to analyze a moisture sensitive pharmaceutical product, it is necessary to produce a moisture sorption isotherm. The water sorption isotherms of foods and pharmaceuticals show the equilibrium relationship between the moisture content and the water activity (A_w) at constant temperatures and pressures. These isotherms are generally described as a plot of the amount of water sorbed as a function of A_w (Iglesias and Chirife, 1982). Packaging dehydrated foods is one of the most important applications of moisture sorption isotherms, since the prediction of storage life of these items packaged in flexible film materials is of considerable value in the food preservation area (Iglesias and Chirife, 1982). The rate of transport of water vapor through a film sample is shown by Eq. (1)

$$dw / d\theta = P A / l \quad (p_i - p_o) \qquad (1)$$

where w is the weight of water transferred across the film, θ indicates the time, P is the film's permeability, l is the thickness of the film, A is film area, p_i is the vapor pressure of water outside the film, and p_o is the vapor pressure of water on the other side of the film. This assumes that moisture entering the package equilibrates with the product almost immediately.

An interesting finding showed that the particle size distribution of a product often does not influence the sorption isotherm (Iglesias and Chirife, 1982). Isotherm equations are needed for evaluating the thermodynamic functions of the water sorbed. The need for mathematical models in order to use the isotherm with computer techniques was discovered.

The moisture isotherm serves as the translation between moisture influx into a hermetically sealed package and the effects of this water vapor on the product (Marsh, Ambrosio, and Guazzo, 1991). Computer modeling can be used to predict the time necessary for the moisture level inside the package to rise from a production moisture level to a critical level under specific environmental conditions. Marsh et al. developed a model for use in shelf life determination. The product examined was a Fibre Trim effervescent tablet, which became the first effervescent tablet to be introduced in a nonfoil package worldwide. This shelf life model calculates the f

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the time for the moisture content within the product to rise from the initial moisture content to the critical content as influenced by the packaging system and environment. Packaging system refers to the package area, package volume, blister permeability and product net weight. Marsh's program considers the change in the driving force of moisture across the package as moisture traverses the film. Shelf life differences reflect the varying environmental conditions of 3 climactic regions at differing times in the product life cycle.

Unit Dose Blister Packaging

Barrier plastics, which may be used for blister packaging, fill the gap between the infinite barriers to moisture mass transfer of metals and glass, and the finite barriers of coated cellulosic products and high permeability plastics. Often times, combinations of materials - laminates, coextrusions, or coated substrates - are necessary to provide for the unique requirements of foods and pharmaceuticals while supplying needed mechanical, thermal, optical and aesthetic properties (Brown, 1987).

Blister packages for pharmaceutical products have several advantages over bottles. Blisters allow for preparation of unit doses without having to physically handle the drug, leading to increased hygiene and better conservation of the drug (Dubouchet and Paisley, 1984). A blister provides good mechanical protection of each individual tablet or capsule, has tamper evident features, and, being transparent, gives easy content identification. Also, blister packages aid in greater flexibility with regard to adapting the package size to the prescription size, reducing inventory requirements.

Over the last several years, there has been an entirely new use for coextruded film and sheet in packaging pharmaceuticals and medical devices in the U.S. (Bonis, 1989). The greatest threats to the physical condition, stability, and potency of drug products are heat, moisture, light and oxygen. Many drug products are completely inactivated by moisture exposure. Penicillin, for example, becomes totally inert unless packaged in containers with low water vapor transmission rates. Moreover, biological products such as vitamins, hormones, vaccines, antitoxins and certain antibiotics can degrade and be inactivated by excessive heat. Light and oxygen together may reduce or nullify the effectiveness of other substances, such as antibiotics, hormones, alkaloids, glucosides, vitamins, steroids (cortisone, prednisone) and vaccines.

Polymonochlorotrifluoroethylene (Aclar) is nearly impermeable to moisture, but it is an expensive material (Bonis, 1989). Aclar is suitable for packaging of pharmaceuticals because of its very low WVTR, fairly low gas transmission rate, inertness to most chemicals, resistance to ozone, clarity, good tear strength and excellent dimensional stability (Brennan, 1992). Due to its dramatically different softening point from other thermoforming materials, Aclar laminates can complicate the thermoforming process. PVC (unplasticized) is one of the most commonly used materials because of low cost and ease of thermoforming. Unfortunately, it generally does not provide decent barrier protection to moisture. However, its barrier characteristics can be improved by lamination with different resins, especially Aclar.

Guise (1984) discussed some of the advantages of blister packaging. Blister packages offer protection against cross contamination, elimination of tablet abrasion caused by vibrations during distribution, decreased chance of overdose by over-the-counter (OTC) users, and storage space savings for reels of base and lidding materials over empty bottles.

Pires et al. (1988) conducted a study which evaluated Ibuprofen product stability in two multiple unit containers (30 and 50 count) and three blister package types. This project ultimately compared the effects of opening and closing the multiple unit containers with the different blister packs (PVC, Aclar/PVC and Saran coated PVC). Moisture sorption isotherms and WVTR data were generated. At the abusive storage conditions (78 $^{\circ}$ F and 85% R.H.), the moisture content of the tablets increased over time, with the greatest increase being in the PVC blister package and followed by the multiple unit 30 and 50 count containers subjected to repeated opening and closing. The Aclar blisters showed the best performance against moisture. Ambient conditions resulted in no significant differences for the five package types. There are advantages to blister packaging in terms of barrier options and the one-time use feature.

Diffusion and Permeability

Hernandez et al. (1986) applied the equilibrium vapor pressure and microbalance gravimetric method (i.e., sorption technique) to study the sorption and diffusion of toluene vapor in OPP and Saran film samples as a function of penetrant concentration. As part of this approach, the polymer sample was hung directly from one of the arms of the electrobalance while a constant concentration of penetrant vapor was flowed continually through the sample hang-down tube, such that the sample was completely surrounded by vapor (Hernandez et al., 1986).

Understanding the diffusion, solubility and permeability of penetrants through plastic film structures is of both theoretical and practical importance. Theoretically, this knowledge can increase the understanding of diffusion mechanisms of penetrants through polymer membranes. Solubility and diffusion of organic penetrants will be critical for instances when product quality is related to the transfer of organic vapors from one element of the package to another element. Diffusion and solubility coefficients are usually determined by weight change observations of a polymer sample during a sorption process (Hernandez et al., 1986).

Diffusion and permeability values can be found from permeability studies where permeant transport through a film sample is monitored (isostatic procedure) or by quantifying the amount of permeant which has passed through the polymer and accumulated over time (quasi-isostatic procedure). The Cahn electrobalance is a very efficient tool for generating data of a vapor being sorbed by a film sample or any other product over a given time period.

At low concentrations, where plasticization is negligible and sorption kinetics are Fickian, the diffusivities of gases and vapors in glassy polymers are extremely strong functions of the size and shape of the penetrant molecules (Berens, 1989).

The rate of permeability is affected by the temperature, humidity, and package surface area; polymer properties such as density, molecular orientation, plasticizer content and chain stiffness. In addition, the hydrophobic or hydrophilic character of the film will affect permeability (Brennan, 1992). Permeation through a plastic film occurs in three stages:

1. Absorption and solution of the penetrant on one polymer surface
2. Diffusion of the penetrant through the polymer
3. Desorption and evaporation of the penetrant from the other polymer surface.

There are several ways in which a gas can permeate a membrane. This will depend on the membrane structure. A material with a capillary porous structure will produce gas transport by the phenomena which takes place in the pores, while a non-porous material will give rise to migration by molecular diffusion (Rudobashta et al., 1978).

Steffe and Singh (1980) conducted a study to determine the liquid diffusivity of the starchy endosperm, bran and hull of rough rice. Mathematical equations based on Fick's Law of Diffusion were used to model the thin-layer drying of brown, white and rough rice. Diffusion coefficients were found by minimizing the sum of squared deviations between the theoretically predicted and observed drying curves. The distinct feature of this research is that this rough rice product is viewed as a composite body with different diffusion properties for each component.

Several assumptions were made in order to develop the drying models used. Specifically:

1. Liquid diffusion is the mechanism of moisture movement.
2. Diffusion coefficients are not a function of moisture concentration.
3. Rice was considered to be isothermal during the drying process.
4. The rough rice kernel was considered as a sphere (starchy endosperm) surrounded by two concentric shells (bran and hull) for geometric purposes.
5. Rough rice components are homogeneous, isotropic materials.
6. Rice kernel shrinkage is negligible during drying.

Fitting Models for Sorption Isotherms

Several mathematical models exist to fit the experimental sorption isotherm data for a given pharmaceutical tablet or food substance. One example is the BET (Brunauer-Emmett-Teller) equation (Iglesias and Chirife, 1982) found below

$$a_w / (1-a_w) X = 1 / X_M C + a_w (C - 1) / X_M C \quad (2)$$

which calculates X_M (the monolayer moisture content). This parameter (X_M) has significance in the physicochemical stability of foods.

Another such example is the Henderson equation (Iglesias and Chirife, 1982)

$$1 - a_w = \exp \{ - [b_2 (X)^{b_1}] \} \quad (3)$$

where X is the moisture content expressed on a percent dry basis, and b_1 and b_2 are statistical parameters to be used for the isotherm description. To represent sorption data for interpolations or inclusion into computer models of drying processes, closed functions are used; the Guggenheim-Anderson-De Boer (GAB) equation is one of the relations most often applied (Spiess and Wolf, 1986).

Until recently, most of the mathematical models for prediction of the shelf life were simple in nature. Some of these models were developed by Labuza, Karel and coworkers and focused on water vapor and oxygen deterioration. Peppas and Khanna have analyzed a mathematical theory of gaseous transport through polymer films, which in connection with a variety of food sorption models, can lead to concise prediction of shelf life of foods in storage environments (Peppas and Sekhon, 1980). With this approach, it is possible to predict shelf life of food products for moisture transport through plastic films, with minimal or no swelling due to sorption, and for sorption on food described by linear, Langmuir, BET, Halsey, Oswin, Freundlich and other isotherms. Generalized graphs were produced which exhibit the dependence of internal water activity on storage time for packaging systems characterized by a permeability-sorption constant. This constant is a packaging system quality and can be found from food sorption and polymer diffusion characteristics, as well as from specific geometric properties of the food package. Additionally, this theory was extended to include such parameters as oxygen diffusion, sorption and reaction on the food product.

The previous mathematical analysis combined diffusive and sorptive concepts in a simple, but accurate fashion. Assumptions inherent in this development include thermodynamically ideal systems, no swelling of the polymer film due to water vapor diffusion (i.e., thermodynamic incompatibility between moisture and polymer), isothermal conditions, single polymer packaging, no pressure difference during packaging, and constant temperature and relative humidity (R.H.) storage conditions (Peppas and Sekhon, 1980). The model also assumes that there is no degradation or physical change of the polymer from time-temperature history, that sorption on the food is the rate limiting step once the vapors have diffused through the film, and that water diffusion through the food is not significant.

The specific amount of water associated with a solid at a particular relative humidity and temperature depends on its chemical affinity for the solid and the number of available sites of interaction. Zografi et al. (1988) studied the situation where various solids of differing moisture contents are mixed together into a solid dosage form and stored in a sealed container at a known temperature and headspace volume. Assumptions include a completely closed system and transfer of moisture occurs via the vapor phase.

A mathematical method to predict the amount of moisture associated with each ingredient in a mixture was presented. This model requires the initial moisture contents of the individual components, their dry weights, headspace volumes, temperature and an equation which can describe the sorption or desorption isotherms for the solid. This approach is significant for desiccant prediction and quantity necessary to maintain a relative humidity in a package. In addition, the headspace volume to be used to reduce moisture sorbed to an active ingredient may be estimated.

Computer Simulation Programs

Various computer simulation programs have been developed at the School of Packaging (Michigan State University, East Lansing, MI) to predict shelf life of moisture sensitive products for a range of temperature and relative humidity values. Kirloskar (1991) interpolated data of the isotherm from data at three temperatures. Two different pharmaceutical products generated the experimental results which were being sought for this program. An orange flavored multivitamin tablet and an Ibuprofen tablet were evaluated. This development provides the effect of temperature on the coefficients of the equation selected to describe the equilibrium sorption isotherm of the tablet. The program combines the expression for the isotherm as a function of temperature and the expression for the water vapor permeability of the package with the equation for predicting the moisture gain of the tablet as a function of storage condition and time, within the three sorption isotherm temperatures.

Kirloskar evaluated three moisture sorption fitting equations as part of the shelf life program. The equations used were the Chen equation, the Henderson equation and the BET equation. The BET and Henderson equations were presented in Eq. (2) and Eq. (3), respectively. Chen's equation is shown in Eq. (4).

$$M = (k - \ln(-\ln A_w)) / a \tag{4}$$

These equations were used to fit the experimental sorption isotherm data. The following criteria were used to select the best fitting equation out of the three possible: 1.) the best linear regression coefficient and, 2.) the minimum sum of the squared difference between the equation and experimental values. Kirloskar's shelf life predictive modeling assumed a steady state mass transfer of moisture through a package expressed as a permeability.

A different approach of a shelf life computer program was presented by Kim (1992). This program estimates the shelf life of a packaged moisture sensitive pharmaceutical product based on the solutions of a set of partial differential equations that correlate the amount of sorbed water by the product and the diffusion coefficient of water of the packaging material and the tablet. The set of differential equations is solved using the finite difference method. Some of the key parameters which are taken into consideration include the diffusion coefficient of water in the pharmaceutical product and the packaging material, as well as the solubility of the material to water.

One conclusion found as part of Kim's work was that the shelf life tends to decrease and reach an equilibrium state as the diffusion coefficient of the tablet and material increases. In addition, Kim observed that when the diffusion coefficient of water in the product is significantly higher than the diffusion coefficient of the packaging material, the shelf life value for a circular plate shaped product was in agreement with an analytical solution. This model should prove to be extremely useful and accurate for package and material selection for a moisture sensitive product.

The shelf life of the pharmaceutical product is associated with the total moisture content in the tablet. Product performance depends on other characteristics besides moisture. The shelf life modeling does not provide information about these issues, such as any degradation from oxygen, light sensitivity, dissolution rate or change in potency of active ingredients. Perhaps at the present time, there is no predictive mathematical model which addresses all product areas. Moisture is the key parameter considered as part of this finite difference model to predict the shelf life by calculating moisture content at different levels (shells) of the tablet and determining the amount of water in the package headspace. All other changes in the quality of the product that affect the product's shelf life has to be correlated with the moisture content.

Contrary to the model that uses permeability, this program, based on a finite difference method, considers the unsteady steady state transfer of moisture through a packaging material, into the headspace of the package and into the food or pharmaceutical product. Due to the development of many polymers with strong resistance to water vapor, this study of mass transfer is useful. Several assumptions are made as part of this simulation program and are found in the following list.

1. Water is transferred through the packaging film and pharmaceutical product by molecular diffusion.
2. Moisture sorption isotherms of packaging material and product are known.
3. The shelf life of the product depends on physical and/or chemical qualities which are only related to the moisture content of the product.
4. The temperature and relative humidity outside the package are constant.
5. Sorption/desorption hysterysis in the product is negligible.
6. The water vapor concentration in the headspace surrounding the product is homogeneous.
7. Initial concentrations of moisture in the product, headspace, and packaging material are all in thermodynamic equilibrium.
8. The diffusion coefficient of the polymer and product depend solely on temperature.
9. Product has simple geometry, such as a sphere or circular plate.
10. If the shape is that of a circular plate, moisture transfer occurs through the circular faces only and not through the edge of the tablet.
11. Diffusion of water vapor into the product is one

dimensional.

12. Product responds to changes in relative humidity instantly by absorbing moisture immediately.
13. Computer model considers only single layer packaging film materials.

The necessary parameters needed to execute this shelf life simulation model include all external conditions and specific characteristics of the packaging material and pharmaceutical product. External conditions were those such as relative humidity, absolute humidity and temperature. Package properties required were blister volume, blister surface area, package thickness, package diffusion coefficient, number of package layers and Henry's Law constant found from the solubility data. For the pharmaceutical tablet, characteristics investigated for this program included the tablet diffusion coefficient, both the initial and critical moisture contents, the dry tablet weight, the tablet radius and thickness, the number of shells used and the three GAB (Guggenheim-Anderson-de Boer) constants. All of these parameters comprised the input data for the mathematical model using the finite difference technique for unsteady state moisture uptake of a packaged product.

The diffusion coefficient of the tablet and the polymer film to water, as well as the solubility of the film to water, are the most critical parameters of this program. These characteristics have the greatest impact on the outcome of the shelf life and exhibit adsorption and diffusion behavior of the water molecules. Polymer structure and percent crystallinity, along with product composition, affect the diffusion. It is important to know the constant temperature and relative humidity conditions outside of the package for the model. Diffusion coefficients of the tablet and material are dependent on the temperature.

Moisture content is the only indicator of moisture the product held before exposure to the external conditions. When the critical moisture content is reached, the shelf life is determined based on the period of time needed to obtain this value. Therefore, the CMC is a required variable of the program.

The GAB equation describes the moisture sorption isotherm of the product. From this equation of sorption character, the GAB coefficients are derived and are needed for the model to function. The GAB equation is ideal for analysis of food and pharmaceutical isotherms.

Blister volume determines package headspace available for the product with specific dimensions.

MATERIALS AND METHODS

Materials

As part of this experimental project, UpJohn Company (Kalamazoo, MI) supplied pharmaceutical tablets and blister packaging materials. The pharmaceutical product was a 20 mg Deltasone tablet (Lot No. 286 HW), which is a brand of Prednisone. This drug is often used as an anti-inflammatory agent for the treatment of arthritis. Deltasone (20 mg) is the active ingredient in these tablets. Calcium stearate, corn starch, FD & C Yellow No. 6, lactose, sorbic acid and sucrose are listed as the inactive ingredients. The following dimensions and characteristics were determined and are listed in Table 1.

Table 1. Tablet dimensions

Tablet Thickness	0.392 cm ± 0.001 cm
Tablet Radius	0.50 cm ± 0.005 cm
Tablet Mass	0.4077 g ± 0.0016 g
Surface Area of Tablet	1.57 cm^2 ± 0.005 cm^2
Volume of Tablet	0.308 cm^3 ± 0.005 cm^3
Shape of Tablet	Flat cylinder plate

The blister packaging film sheet construction consisted of 7.5 mil Polyvinyl Chloride / Adhesive layer / 1.6 mil Aclar from inside to outside. The following dimensions and characteristics were determined in Table 2. Figure 1 shows a schematic of a single blister cavity with thickness variations of the formed blister.

Table 2. Dimensions of blister package

Height of Blister	0.65 cm ± 0.005 cm
Radius of Blister	0.625 cm ± 0.005 cm
Surface Area of Blister Package	3.78 cm^2 ± 0.005 cm^2
Inner Volume of Blister	0.80 cm^3 ± 0.005 cm^3

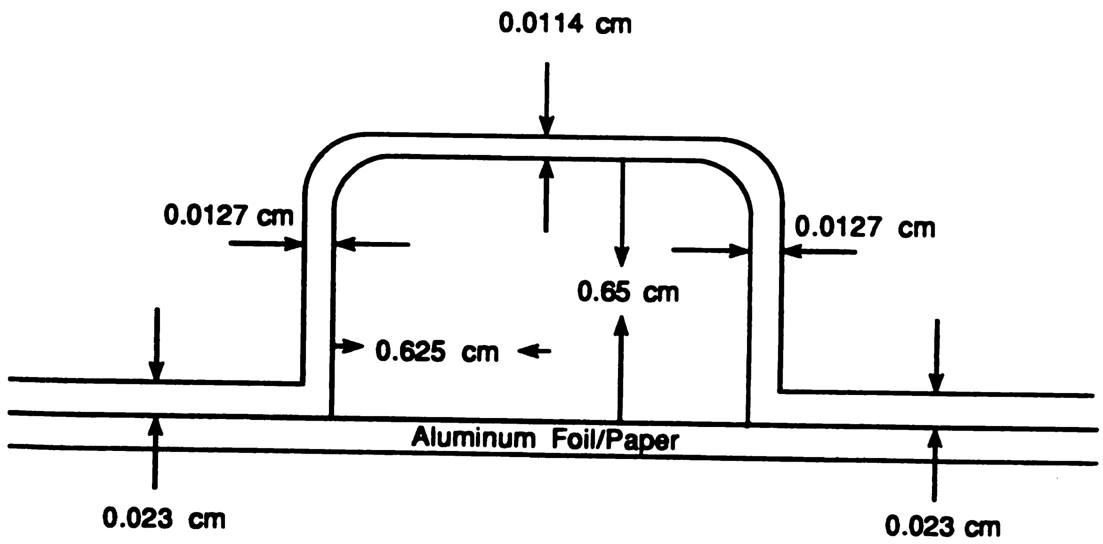


Figure 1. Schematic of a blister cavity with thickness measurements

MOISTURE SORPTION ISOTHERM OF TABLET

Sample Preparation

For the determination of moisture gain over a specific period of time, the Cahn D-200 Model Electrobalance was used. This is a very sensitive mass measurement instrument. The electrobalance is able to detect mass changes as small as 0.1 microgram and is computer operated. The data which was generated by the electrobalance was stored in and retrieved from the hard disk in the computer, and plotted on a plotter using the Cahn software package. A detailed drawing of the electrobalance and the hangdown tube where the sample was held is shown in Figure 2.

The sample tablet used to generate data for the moisture sorption isotherm was prepared in the following manner. A thin strip of aluminum foil was cut to the same dimension as the tablet thickness and attached with adhesive around the entire edge of the tablet. Epoxy resin/hardener (Elmers) was used as the adhesive. The two end tabs of the foil were adhered to one another to form a "tab" and the tablet/foil arrangement was allowed to set for at least two hours. This aluminum strip surrounding the tablet was done in order to fully seal off the edge of the product so that moisture exposure could occur only at the two tablet faces. It was desirable to have water vapor enter only the tablet faces and not the edge, due to the single dimension diffusion character

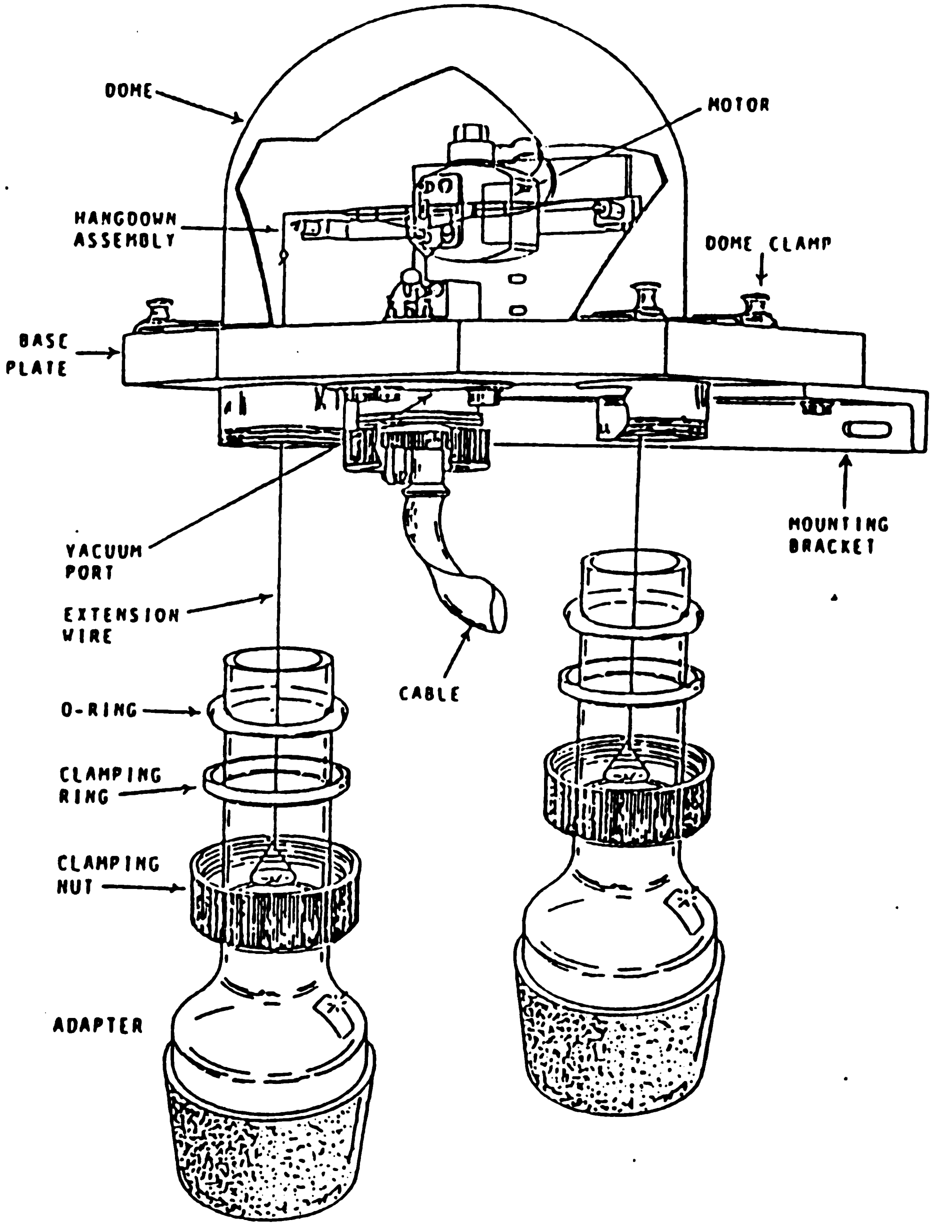


Figure 2. Cahn Electrobalance and hangdown tube for sample

of the shelf life predictive model. A sketch of the tablet/foil sample is in Figure 3. A tiny pinhole was formed in the foil "tab" producing an area for a hanger-shaped wire to be placed.

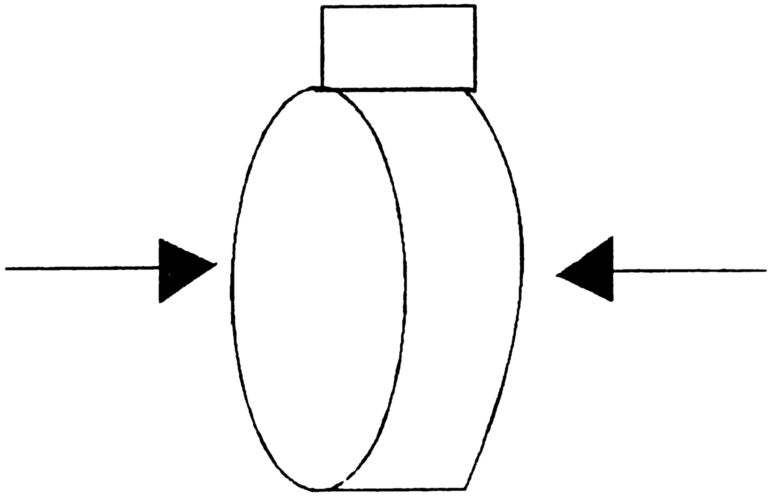


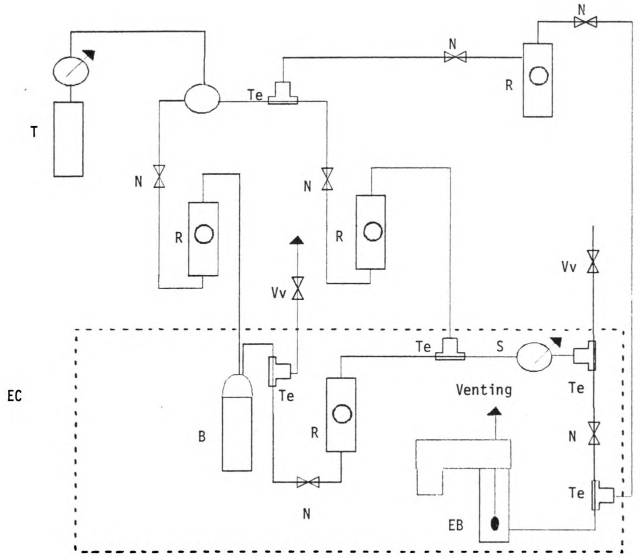
Figure 3. Deltasone tablet sample with foil on edge

Drying the Tablet

The tablet was dried to nearly 0% moisture content in a vacuum oven for 4 - 6 hours at room temperature. A metal stand was put into a large glass beaker in order to support the tablet and wire while drying. During this time, the electrobalance went through a calibration process. After drying the sample, it was quickly moved to the electrobalance tube inside of the environmental chamber and hung from the electrobalance hangdown wire. Additional drying took place through nitrogen flushing until the sample displayed a steady state condition. The sample tablet was contacted with several relative humidity values ranging from 11.50 to 91.70% R.H. at 25.0 ° Celsius. It was possible to measure the relative humidity condition with the use of hygrosensors attached to a hygrometer (Newport Scientific HYGRODYNAMICS, Newport Scientific, Inc., 8246 E. Sandy Court, Jessup, MD 20794-0189). The relative humidities considered were 11.50%, 15.25%, 23.20%, 27%, 34.50%, 40%, 48.80%, 60.35%, 66%, 73.40%, 77.75%, 82.45%, 87.30% and 91.70%. These values were used to construct the moisture sorption isotherm for the product. A schematic of the electrobalance and system can be found in Figure 4.

Sorption Isotherm of Blister

The blister film material, a laminate of PVC film and Aclar, was delaminated in order to analyze the components of the structure on an individual basis for moisture sorption character. This was necessary to determine the diffusion coefficient of water through both polymers. Also, this delamination can ultimately show that separation of these materials doesn't affect their overall properties, such as water vapor transmission and permeability. Each material



T - Nitrogen tank
Te - Tee connection
EC - Environmental Chamber
EB - Cahn electrical balance
Vv - Venting valve
S - Humidity sensor
N - Needle valve
R - Rotameter
B - Gas washing bottle

Figure 4. Schematic of electrobalance and actual system

sample was 6.45 cm^2 and was cleaned with Hexane to remove any remaining adhesive. Each sample was given a pinhole in order to hang from a small wire. A similar procedure employed to dry the pharmaceutical tablet was utilized for drying these film samples. Relative humidities studied were approximately 26.90%, 43.50%, 58.20%, and 77%.

I. R. Identification

The two blister packaging film samples, PVC and Aclar, were analyzed using a Perkin Elmer Infrared Spectrophotometer. The PVC sample required the Attenuated Total Reflectance unit (ATR) due to its thickness being in excess of a few mils. This unit, with the aid of specific angled mirrors and a crystal attachment, allows a clear scan to be obtained on thicker plastic films. Standard IR transmission techniques were used to generate a scan of the Aclar material. Before running the samples on the IR Spectrophotometer, they were cleaned with Hexane in order to remove any adhesive that could have been remaining after delamination of the material. IR scans provide the distinct identification that is characteristic of various materials. IR transmissions were conducted to verify that the PVC and the Aclar had no additional adhesive left after delamination and for individual film identification purposes.

Water Vapor Transmission Rate of Packaging Material

Water Vapor Transmission Rates (WVTR) were determined for the blister materials using a dish method (ASTM E96). Three different samples were prepared in triplicate. There was a PVC sample, an Aclar sample, and a sample of the PVC/Aclar lamination which were tested. Each dish was cleaned thoroughly and enough fresh desiccant was added to cover the bottom of the dish. Circular samples of each material were cut out and sealed to a dish with a hot paraffin wax mixture. The dishes were weighed on a Mettler Analytical Balance and placed into an environmental chamber at 37.78 ° C and 85% R.H. These dishes were weighed 4 separate times over a 1.25 month time period. The WVTR of these materials was calculated based on the weight gain of the dish samples.

Moisture Gain of the Tablet and Blister Package

As an experimental way to validate the calculation of shelf life, Deltasone tablets packaged in blisters were also studied for moisture uptake over time. Two separate relative humidity environments with controlled conditions were created using salt solutions in tightly closed 5 gallon plastic (high density polyethylene) buckets. Salt solutions were prepared by adding the specific salt to a crystallization dish containing warm distilled water until saturation was clearly visible. One humidity condition was 78.5 - 80% R.H. and was prepared with Ammonium Sulfate $(NH_4)_2SO_4$. The other environmental container used Potassium Nitrate (KNO_3) to provide a humidity condition of 88.5 - 90% R.H. The relative humidity levels were measured with a digital hygrometer periodically.

Five full blister cards were placed inside of each bucket, along with one empty blister card to be used as a control. Each blister card contained 10 blisters and held a total of 10 tablets. The packages were weighed over a several month period in order to monitor weight gain with a Mettler Analytical Balance. Forceps were used to handle the blisters at all times. Before placing in to the controlled humidity buckets, all of the blister packages were dried in a convection oven at 40.0 $^{\circ}$ C, until a steady state weight occurred.

RESULTS AND DISCUSSION

Tablet Sorption

Sorption equilibrium experiments were conducted using the Cahn electrobalance at 25.0 ° C. Equilibrium moisture values of the tablet were obtained at selected conditions of humidity, such as 0, 11.50, 15.25, 23.20, 27, 34.50, 40, 48.80, 60.35, 66, 73.40, 77.75, 82.45, 87.30 and 91.70% R.H.. Since the electrobalance operates by a stepwise change of the humidity value surrounding the tablet, several sorption experiments were necessary to carry out the whole isotherm. Besides obtaining the moisture equilibrium value, this mode of operation allowed the determination of the diffusion coefficient of water at various values of relative humidity.

The electrobalance, in combination with the computer and software, allowed for storage of the tablet weight at a specific time point. The amount of time between each tablet weighing was selected prior to the experimental test at a given relative humidity. For each humidity test, the time was expressed in hours, and the weight gain of the tablet (M_t) was calculated. For each experiment, there was an initial weight, W_i, and an equilibrium weight. The equilibrium weight of one experiment became the initial weight for the next interval of humidity. Moisture weight gain, M_t, of the tablet is calculated as

$$M_t = W_t - W_i \tag{5}$$

where W_t is the tablet weight at time (t) and W_i is the initial tablet weight. The final tablet weight gain (M_∞) is calculated as

$$M_\infty = W_f - W_i \tag{6}$$

where W_f indicates the equilibrium weight of the tablet at the end of an experimental humidity value. From these values, M_t/M_∞ was determined by dividing each consecutive weight gain, M_t, by the final weight gain, M_∞. Values of M_t/M_∞ were plotted against time (t), as well as M_t vs. time (t). An example of this is represented in Figure 5. Nearly all of the graphs for the tablet displayed a rapid weight gain of water vapor and then leveled off at steady state.

Material Sorption

The individual PVC and Aclar film samples were also used to calculate the moisture sorption for the packaging material. Similar graphs were produced to illustrate the moisture gain of PVC and Aclar at selected relative humidities. A typical graph of the moisture uptake by PVC film is presented in

Figure 6, and Aclar film shows a similar type plot which is presented in Figure 7. This allows a graphical analysis to be generated of the films' sorption character over a given humidity range. It was found that

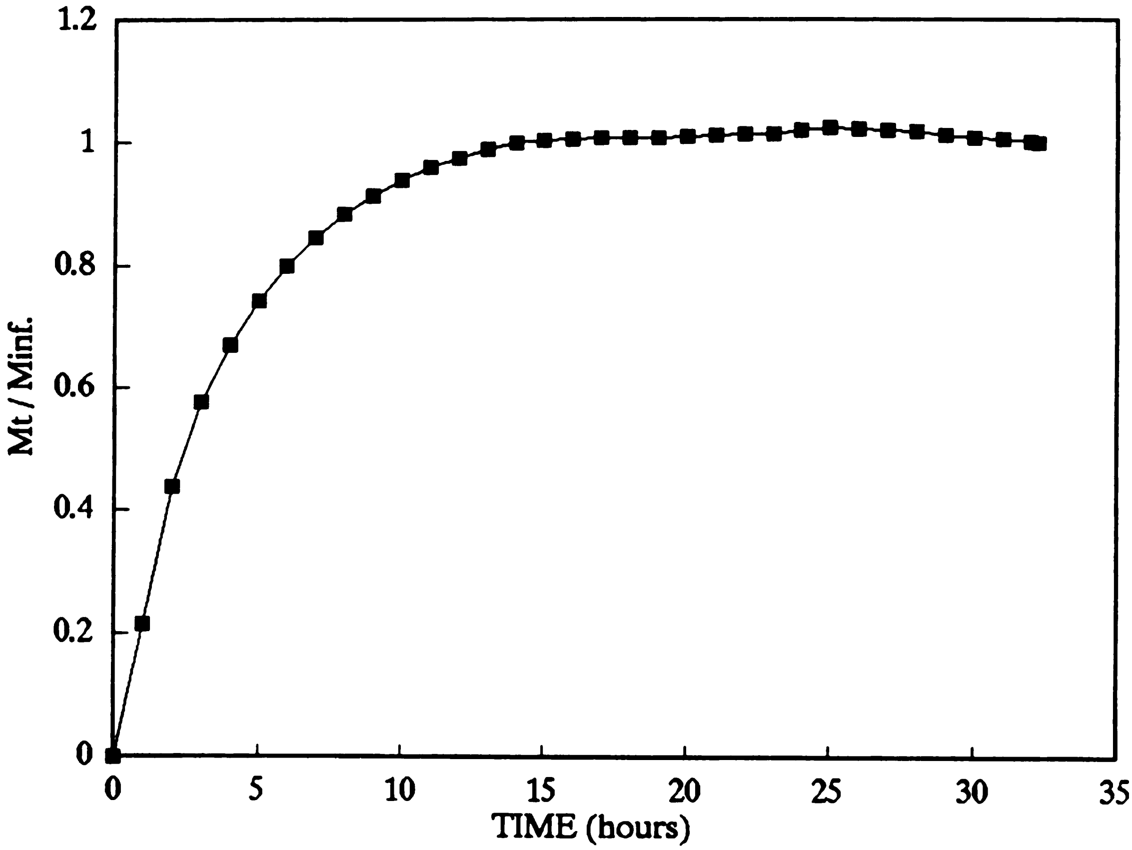


Figure 5. Experimental sorption of tablet at 82.05-87.30% R.H., 25.0 ° C

both films absorbed moisture rapidly and attained steady state within 5.0 hours for relative humidity levels ranging from 0 to 26.90% R.H. for PVC film and within 2.0 hours for relative humidity levels ranging from 43.50 to 58% R.H. for Aclar film.

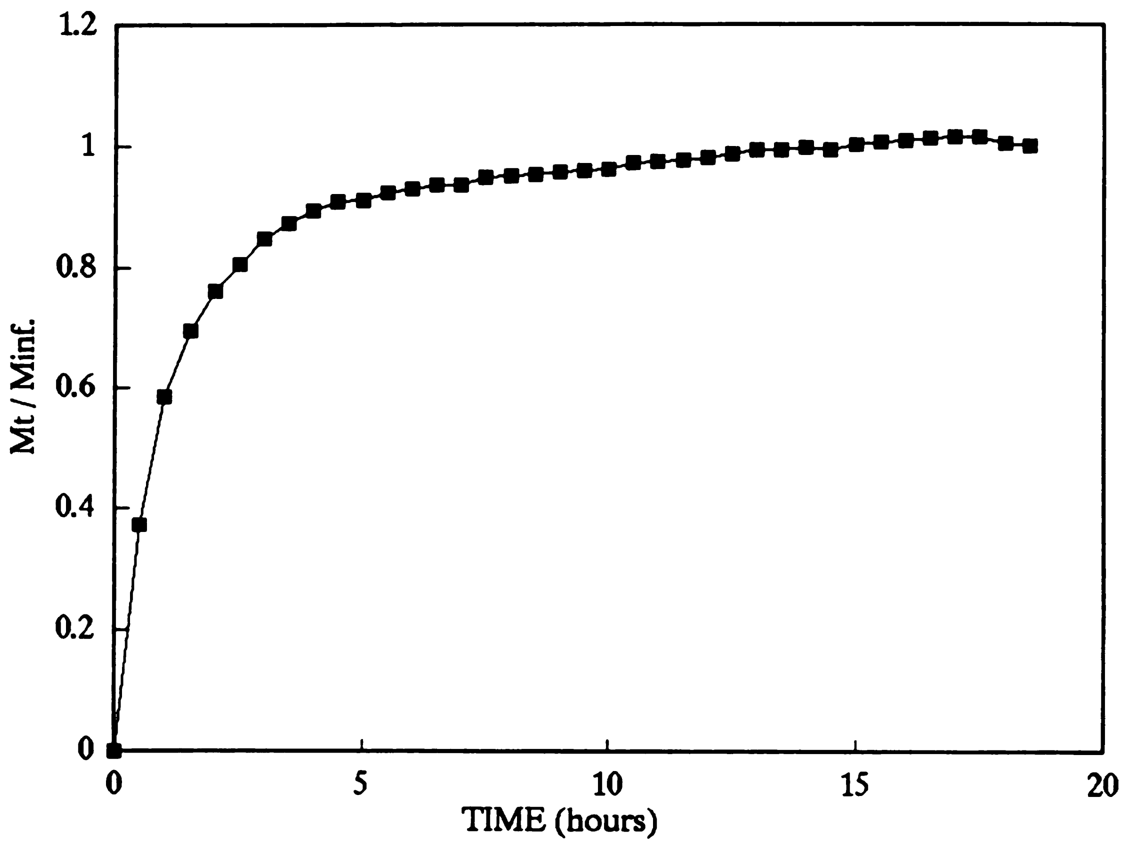


Figure 6. Experimental sorption of PVC film at 0 - 26.90% R.H., 25.0 ° C

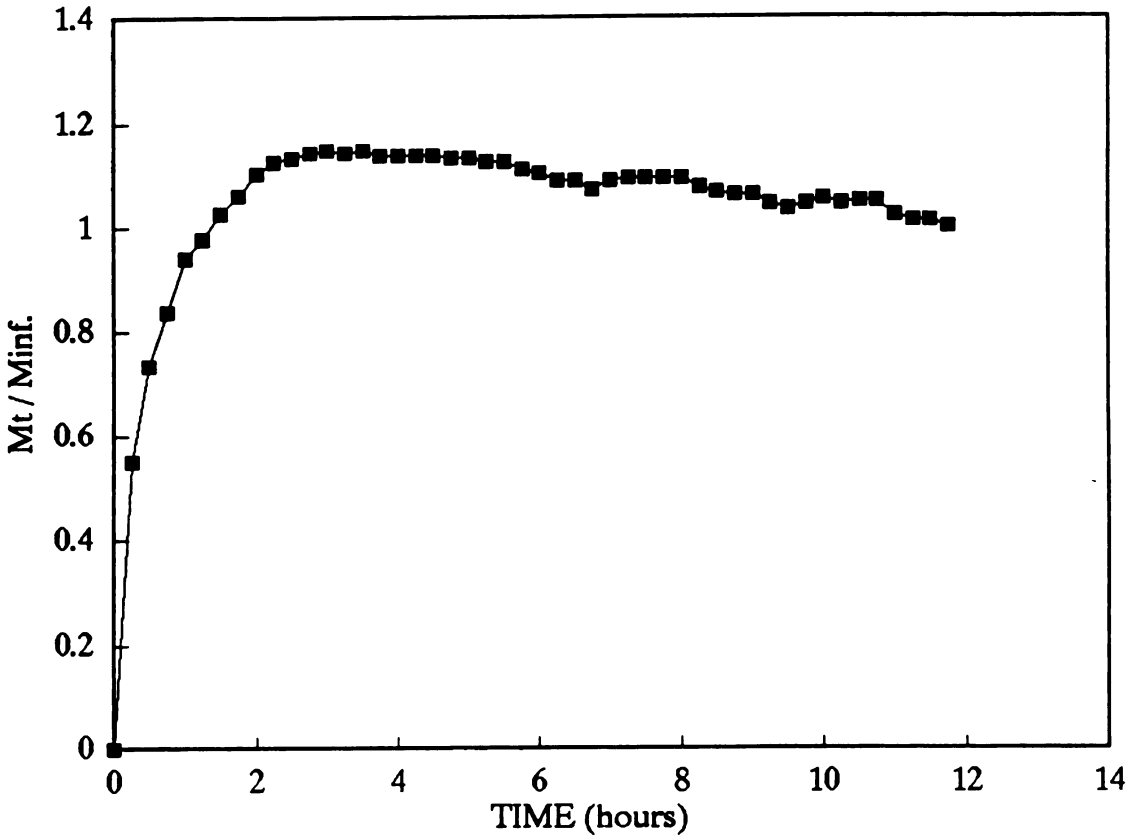


Figure 7. Experimental sorption of Aclar film at 43.50-58% R.H., 25.0 $^{\circ}$ C

Sorption Isotherm

For each value of relative humidity, the equilibrium moisture content (EMC) of the product is defined as the gain of moisture per 100 grams dry weight of product or packaging material and is calculated in the following equation.

$$EMC = [(W_f - W_i) / (W_i)] \times 100 \qquad (7)$$

A moisture sorption isotherm can be generated by plotting EMC against relative humidity. The isotherm gives the amount of water per unit of dry weight of the substance at a particular humidity value at a given temperature. A sorption isotherm describes the manner in which the moisture content will change due to relative humidity fluctuations. Isotherms can also be plotted using EMC vs. A_w (water activity) per Eq. (8). For the Deltasone tablet, the greatest increase in the moisture content occurred between 87.30 and 91.70% R.H. (last point on isotherm). The actual isotherm data is given in Table 3. This isotherm is presented in Figure 8. Equation 8 is described below.

$$A_w = p/p_o = \text{Relative Humidity}/100 \qquad (8)$$

In this equation, p is the water vapor pressure of the product and p_o is the saturation vapor pressure of pure water at the temperature of test (Iglesias and Chirife, 1982). Isotherms are typically similar for most pharmaceutical products.

The sorption isotherms for the Aclar and PVC film samples were generated using the same techniques described for the Deltasone tablet above in Eq. (7). The moisture sorption isotherms for the packaging materials showed fairly linear curves. Increases in moisture content were quite consistent at the various levels of relative humidity. Tables 4 and 5

Table 3. Moisture sorption isotherm data for Deltasone tablet at 25.0 ° C (Experimental and Calculated)

Relative Humidity (%)	Exp. Equilibrium Moisture Content (g H_2O/100 g dry)	Calc. Equilibrium Moisture Content (g H_2O/100 g dry)
0	0	0
11.5	0.375	0.441
15.25	0.394	0.485
23.2	0.524	0.562
27.0	0.642	0.598
34.5	0.699	0.673
40.0	0.743	0.734
48.8	0.932	0.851
60.35	1.05	1.062
66.0	1.221	1.202
73.4	1.365	1.451
77.75	1.606	1.653
82.45	1.904	1.938
87.3	1.976	2.351
91.7	3.514	2.917

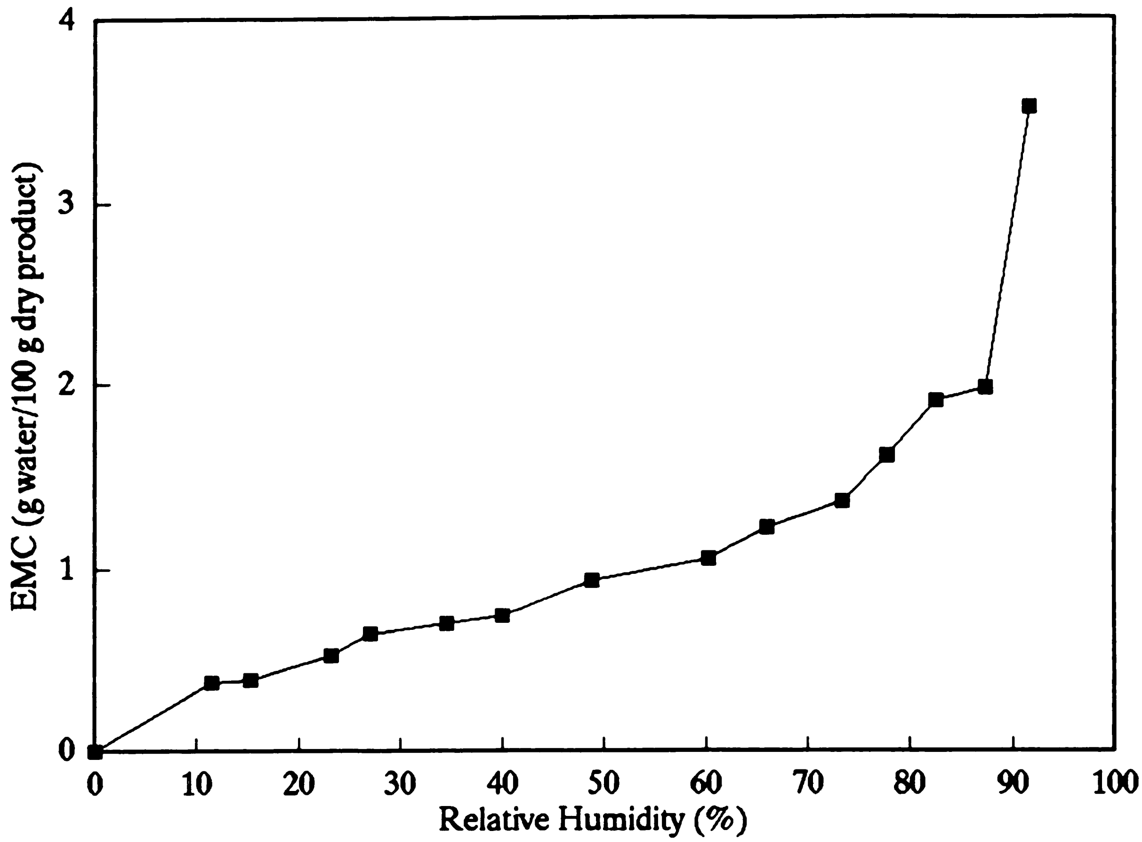


Figure 8. Moisture sorption isotherm of 20 mg Deltasone tablet at 25.0 ° C showing Equilibrium Moisture Content (EMC) vs. relative humidity

provide the sorption data for the PVC and Aclar film. Moisture sorption isotherms for the PVC and Aclar material samples are presented in Figures 9 and 10, respectively.

Table 4. Moisture sorption isotherm data for PVC film at 25.0 ° C

Relative Humidity (%)	Equilibrium Moisture Content (g H_2O/100 g dry)
0	0
26.9	0.036
43.5	0.076
58.2	0.10
77.0	0.133

Table 5. Moisture sorption isotherm data for Aclar film at 25.0 ° C

Relative Humidity (%)	Equilibrium Moisture Content (g H_2O/100 g dry)
0	0
27.35	0.055
43.5	0.084
58.0	0.121
74.45	0.131

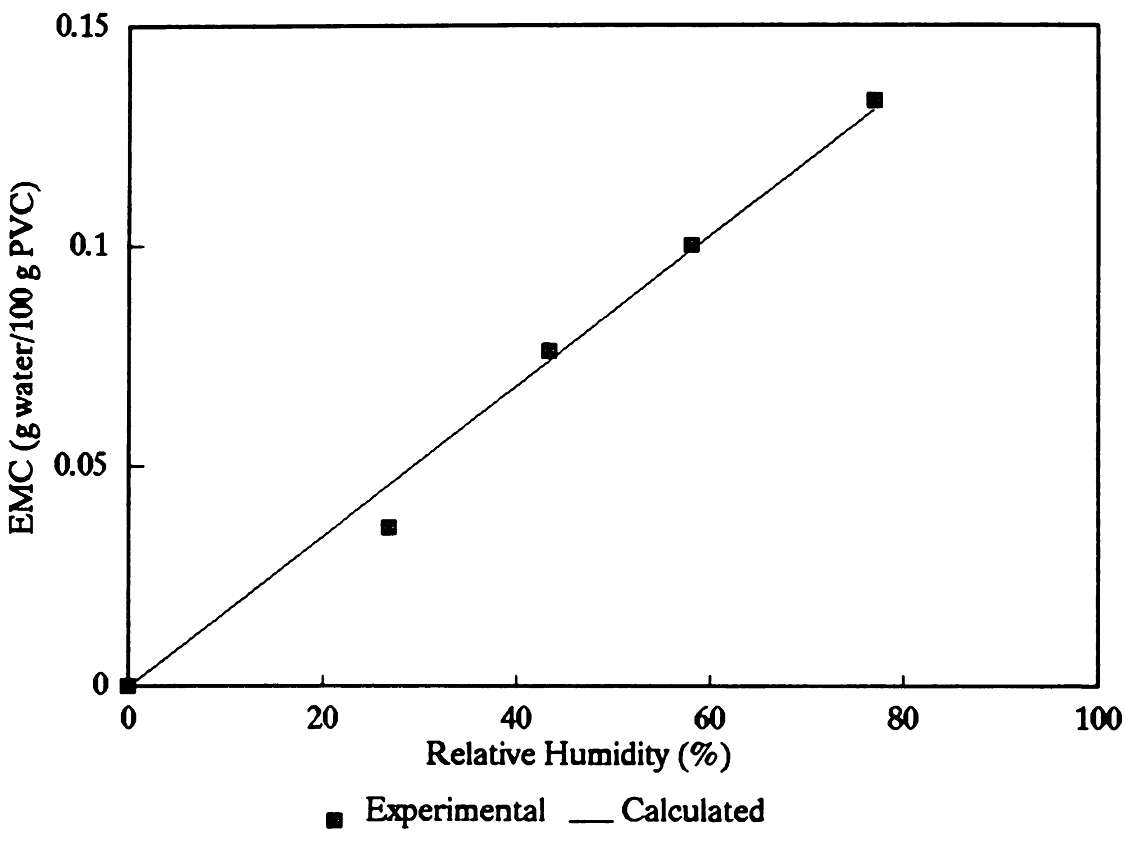


Figure 9. Moisture sorption isotherm of PVC film at 25.0 ° C showing Equilibrium Moisture Content (EMC) vs. relative humidity

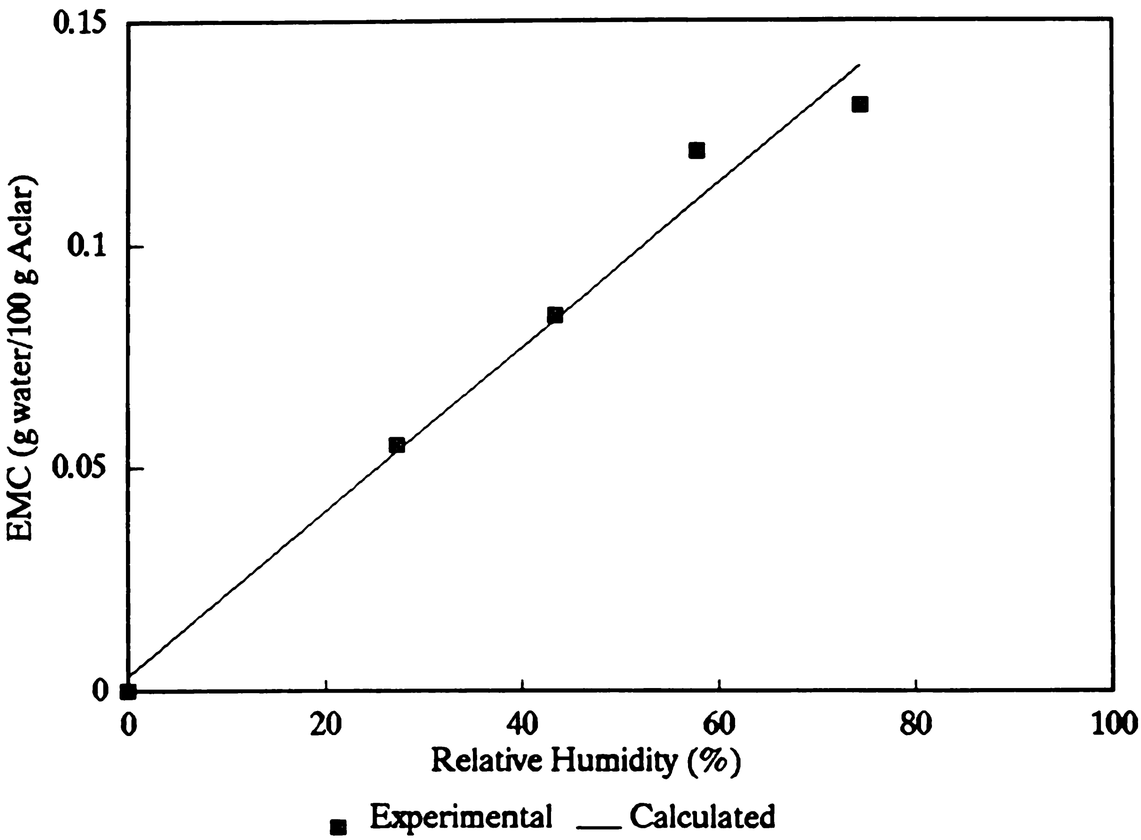


Figure 10. Moisture sorption isotherm of Aclar film at 25.0 °C showing Equilibrium Moisture Content (EMC) vs. relative humidity

Solubility of Packaging Material

The linear change in moisture content by the PVC and Aclar materials can be described by Eq. (9). The slope of Eq. (9) gives the solubility coefficient of both the PVC and Aclar materials.

$$EMC = k \text{ Relative Humidity} \qquad (9)$$

For this equation, k is the slope of the sorption isotherm. For PVC, the solubility coefficient was found to be 0.001704 g H_2O/100 g PVC % R.H. (see Appendix C). A solubility coefficient of 0.001838 g H_2O/100 g Aclar % R.H. was calculated for Aclar film (see Appendix D).

Water Vapor Transmission Rate of Materials

The ASTM dish method (ASTM E96) was applied to determine the Water Vapor Transmission Rate (WVTR) of the various blister packaging materials. Continuous weight gain of the desiccant filled metal dishes was monitored over a specific period of time. This illustrated the passage of water through the material over time, which resulted in moisture gain of the desiccant.

$$WVTR = \Delta W / A * T \qquad (10)$$

ΔW is the weight change over time (g), A is the surface area of the exposed material (m^2), and T is the time period of the test (day). The WVTR test was conducted at 37.78 °C and 85% R.H. over a 35 day interval. Surface area is calculated using

$$A = \pi r^2 \tag{11}$$

where r is the radius of the circular film section within the dish. Graphs of dish weight gain over time for each material display water vapor transmission properties. Results are presented graphically in Figure 11 (PVC), Figure 12 (Aclar), and Figure 13 (PVC/Aclar). Film samples of PVC, Aclar, and PVC/Aclar were analyzed in triplicate for this experiment (see Appendix E).

In order to evaluate the packaging materials, it was necessary to determine the permeability and the diffusion coefficients for the PVC and the Aclar samples. The WVTR and P were measured experimentally for each individual material and for the laminate structure in order to compare the results. With the following equation, the calculated composite WVTR ($WVTR_T$) may be analyzed against the actual data generated.

$$1/WVTR_T = 1/WVTR_{PVC} + 1/WVTR_{Aclar} \tag{12}$$

It was found that the calculated WVTR was very close to the WVTR obtained in the laboratory with 0.169 g/m^2 day

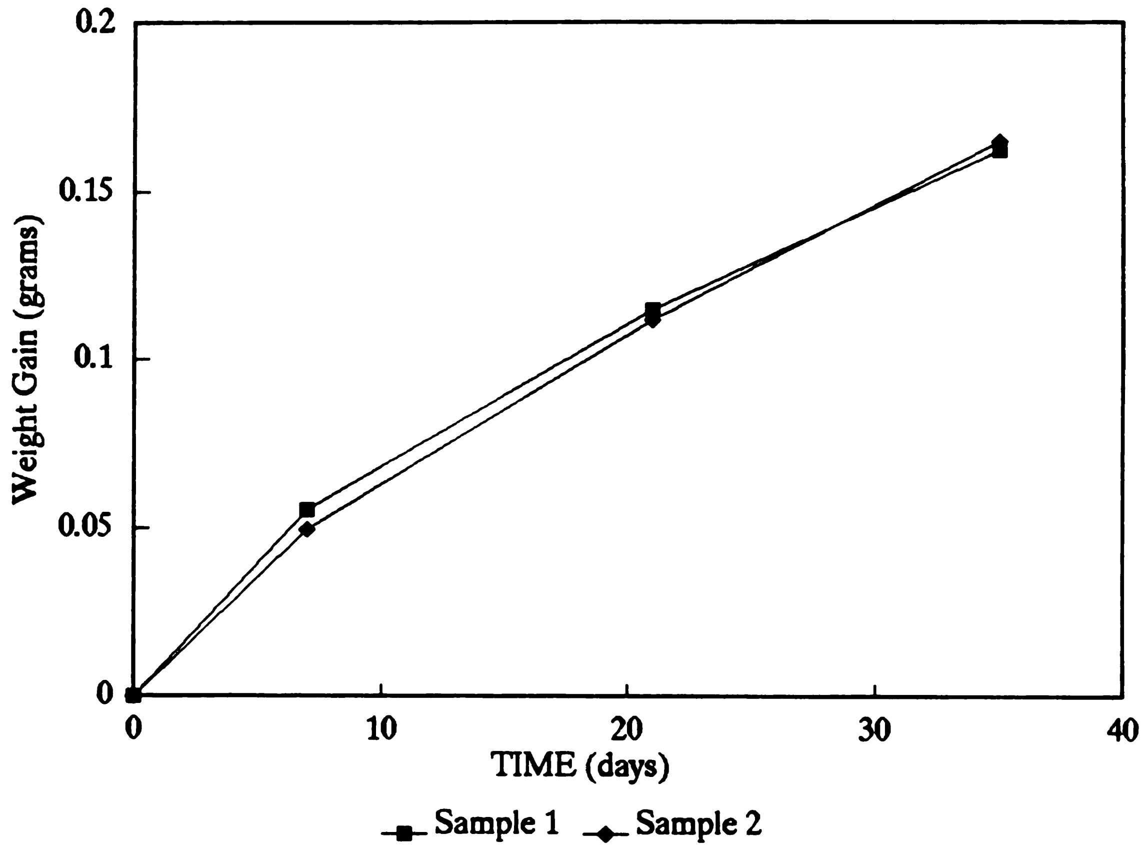


Figure 11. WVTR of PVC film at 37.78 ° C and 85% R.H.

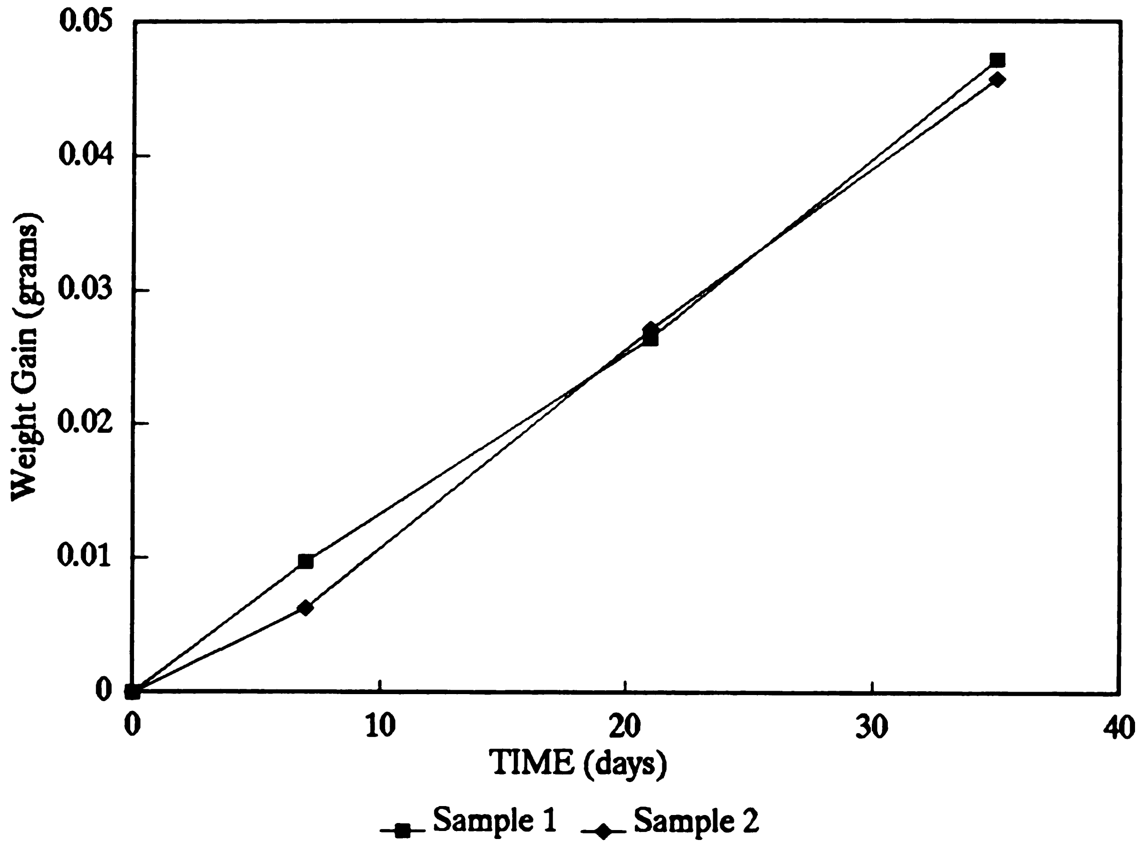


Figure 12. WVTR of Aclar film at 37.78 ° C and 85% R.H.

Weight Gain (grams)

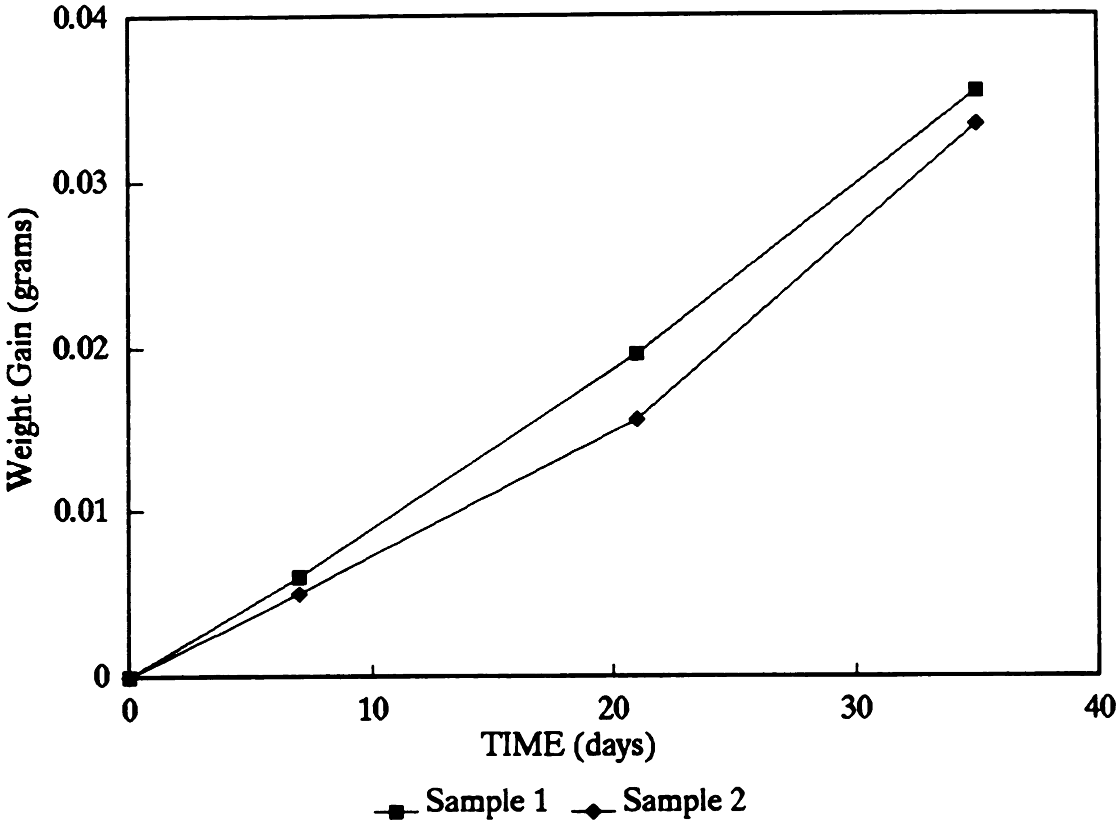


Figure 13. WVTR of PVC/Aclar film at 37.78 ° C and 85% R.H.

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$P_{kc,a}$

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(calculated) and 0.1616 g/m² day (average experimental).

In addition, a comparison of the permeability (experimental) for the laminate blister material and the calculated permeability was determined. Eq. (13) provided the results of the permeability for the total laminate.

$$P_T = L_T / ((L_{PVC} / P_{PVC}) + (L_{Aclar} / P_{Aclar})) \quad (13)$$

P_T is the permeability for the total film structure, L_T is the total thickness of the laminate, L_{PVC} is the thickness of the PVC sample, L_{Aclar} is the thickness of the Aclar, and P_{PVC} and P_{Aclar} are the permeability values for the PVC and the Aclar, respectively. Permeability is calculated from the following equation. Experimental permeability (average) was found to be 0.0348 g mil/m² day mmHg and the comparative calculated permeability was 0.0364 g mil/m² day mmHg showing outstanding agreement of the laminate structure.

$$P = WVTR * L / \Delta p \quad (14)$$

P is the permeability, L is the thickness of the material sample and Δp is the change in pressure of the internal and external environment of the film.

Permeability may also be expressed using other variables as noted below.

$$P = D * S \quad (15)$$

D is the diffusion coefficient and S is the solubility coefficient.

It was critical to show the correlation between the calculated WVTR and permeability of the laminate and the experimental WVTR and permeability values for the laminate. This helped to verify that separation of the composite film into PVC and Aclar layers can yield expected and accurate results for most film characteristics.

Diffusion Coefficient

The diffusion coefficients for water vapor through both the Deltasone pharmaceutical tablet and the packaging films need to be determined as a parameter in the finite difference method computer program (Kim, 1992). For the circular plate shaped pharmaceutical product, the diffusion coefficient is described by the following expression

$$D = 0.049\ L^2\ /\ t_{1/2} \qquad (16)$$

where L is the average thickness of the tablet (cm) and $t_{1/2}$ (seconds) is half the time required for M_t/M_∞ to reach the equilibrium steady state condition at any given relative humidity value.

It is important to discuss the procedure used to calculate the diffusion coefficient for the tablet, as well as the packaging materials. The diffusion coefficient takes into account the $t_{1/2}$ value as seen from Eq. (16). $T_{1/2}$, the time required to reach one half of the steady state, was difficult to identify exactly. Therefore, several $t_{1/2}$ values were analyzed to produce several D values. Based on Eq. (17), various curves of M_t/M_∞ were generated using the different tablet diffusion coefficients. At any given relative humidity range, the experimental M_t/M_∞ vs. time was compared to the calculated M_t/M_∞ vs. time using a least squares method. This method involved taking the sum of the differences squared for the M_t/M_∞ values (calculated and experimental). The diffusion coefficient which provided for the least sum was used as the result for a particular humidity level (see Appendix B). Product diffusion is a required component of the shelf life model. This process should improve the accuracy for the determination of the diffusion coefficient.

The mass uptake of a flat specimen surrounded by a sorbate at constant concentration is given by the following equation (Crank, 1975).

$$M_t/M_\infty = 1-8/\pi^2 \ [\exp(-D \pi^2 t/L^2) + 1/9 \exp(-9 D \pi^2 t/L^2)] \quad (17)$$

This equation allows a comparison between the calculated M_t/M_∞ values and the experimental M_t/M_∞ values. Figure 14 presents a comparison of the calculated and experimental moisture uptake curves for the Deltasone tablet. It is evident from the two curves that the agreement is excellent for the experimental and calculated data.

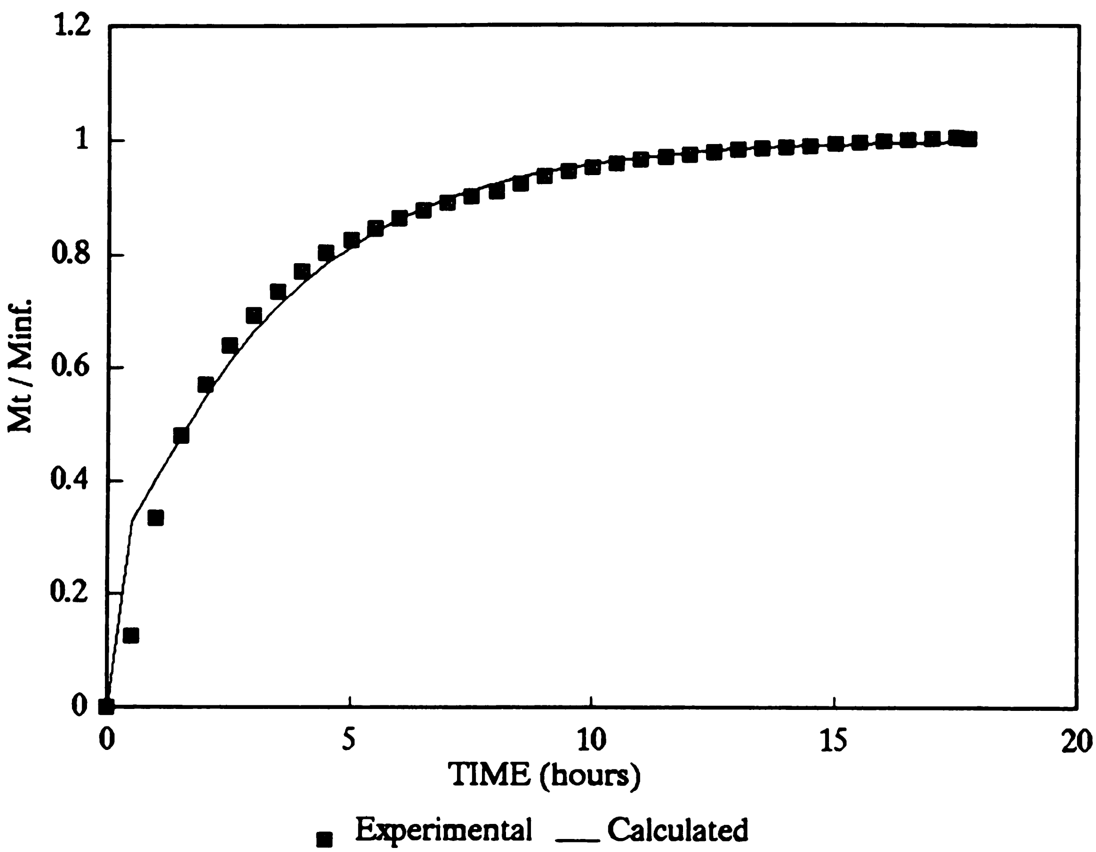

Figure 14. Comparison of experimental and calculated M_t/M_∞ for 20 mg Deltasone tablet at 72.25 - 77.75% R.H. and 25.0 $^\circ$ C

The values for the diffusion coefficient which were calculated for the Deltasone tablet had some degree of variability across the different humidity levels. This variability may have been caused by the change in environmental conditions (relative humidity). Based on the calculation for the diffusion coefficient, the $t_{1/2}$ value is the only variable which can fluctuate with the humidity as the average thickness of the tablet remains constant. Therefore, the time required to obtain half of the steady state condition varied with the R.H. in this instance. Diffusion coefficient results extended through the range of 0.603 E -06 cm^2/sec. at 40.75 - 48.80% R.H. to 1.62 E -06 cm^2/sec. at 66 - 73.40% R.H. The standard deviation was found to be 3.30 E -07 cm^2/sec. Table 6 summarizes the values for the diffusion coefficient of water at various relative humidity levels. Figure 15 shows the graphical presentation of the tablet diffusion coefficient and the relative humidity. It is evident that there is no trend in the data.

For the tablet, the average diffusion coefficient value was used in the shelf life computer program.

Equation (16) was used to compute D for the film samples and the tablet. Figure 16 and Figure 17 demonstrate the same concept for the packaging materials as Figure 14 showed for the tablet comparison (see Appendices C and D). Again, the experimental and calculated moisture uptake profiles are very similar. Many of the points coincide graphically. These figures are shown below. Table 7 lists the diffusion coefficients of water for the PVC film sample and the Aclar film sample at two relative humidity ranges.

When a laminate is composed of two layers of thickness in series, L_1 and L_2, and two diffusion coefficients, D_1 and D_2, the effective diffusion coefficient, D, is given by the following equation (Crank, 1975).

$$(L_1 / D_1) + (L_2 / D_2) = (L_1 + L_2) / D \quad (18)$$

This equation can also be written as shown in Eq. (19).

$$D = (L_1 + L_2) / ((L_1 / D_1) + (L_2 / D_2)) \quad (19)$$

The effective diffusion coefficient was used in the shelf life computer program and was calculated to be 2.0 E -09 cm^2/sec.

Table 6. Diffusion coefficient of tablet at R.H. conditions.

Relative Humidity (%)	Diffusion Coefficient (cm^2/sec.)
0 - 11.50	1.22 E -06
36 - 40	0.85 E -06
40.75 - 48.80	0.603 E -06
60.70 - 66	1.26 E -06
66 - 73.40	1.62 E -06
72.25 - 77.75	1.27 E -06
77.90 - 82.45	1.60 E -06
82.05 - 87.30	0.996 E -06
Average	1.179 E -06
Standard Deviation	3.30 E -07

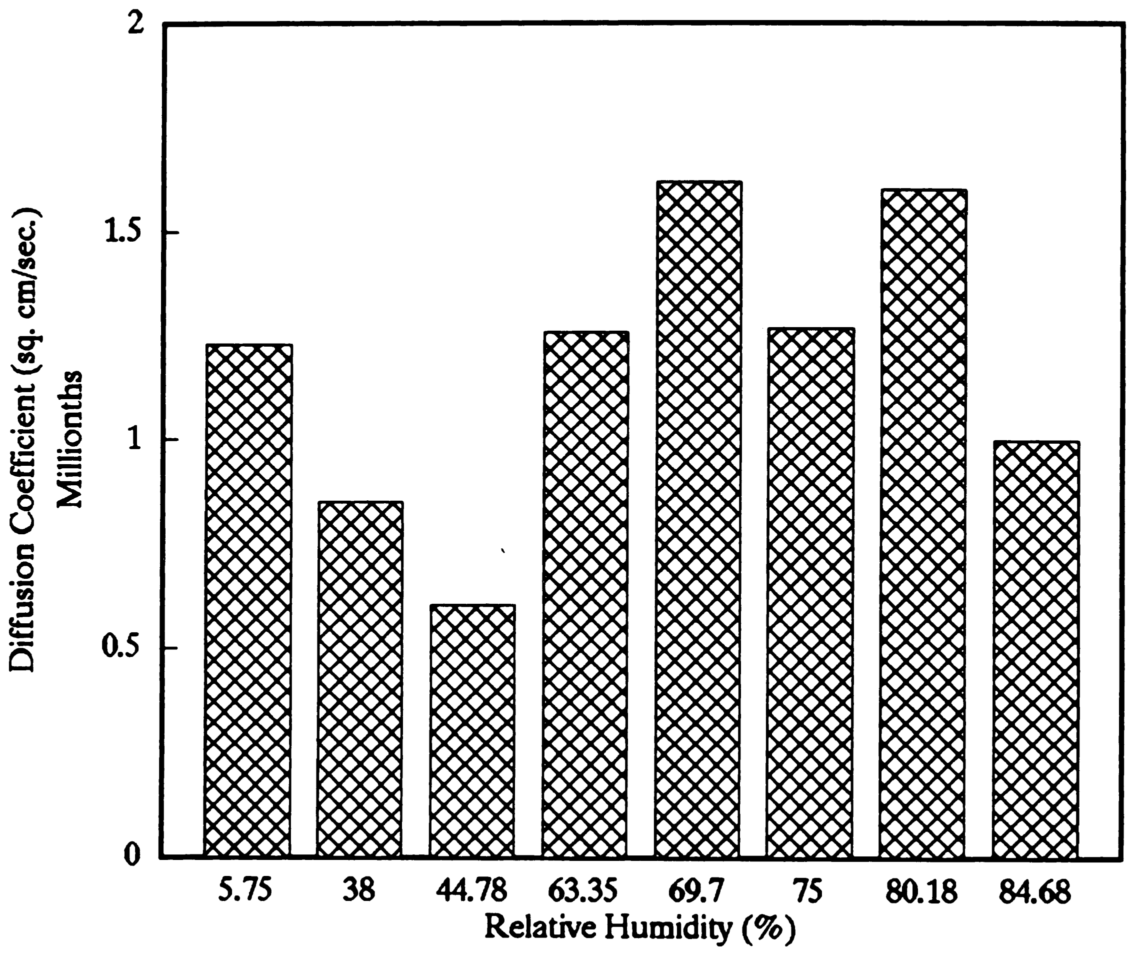

Figure 15. Diffusion coefficient of Deltasone tablet over R.H. ranges at 25.0 ° C

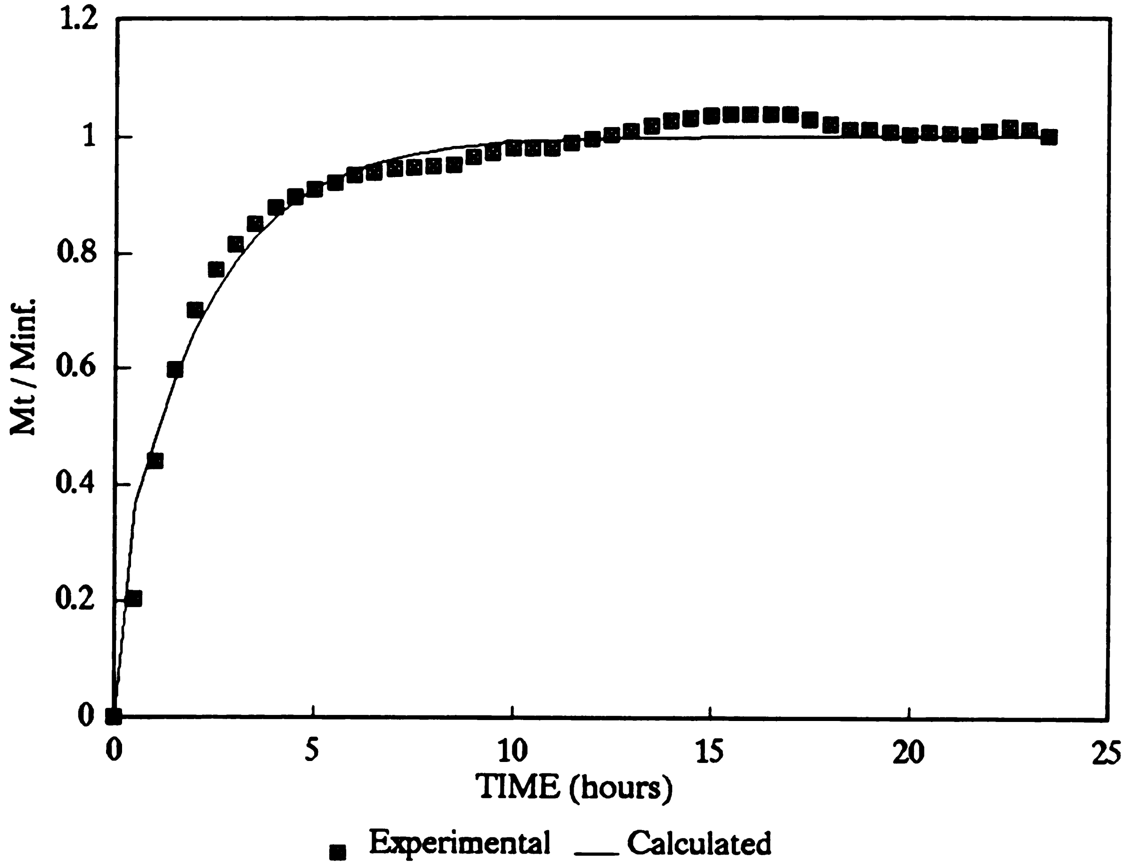

Figure 16. Comparison of experimental and calculated M_t/M_∞ for PVC film at 58.20 - 77% R.H. and 25.0 $^\circ$ C

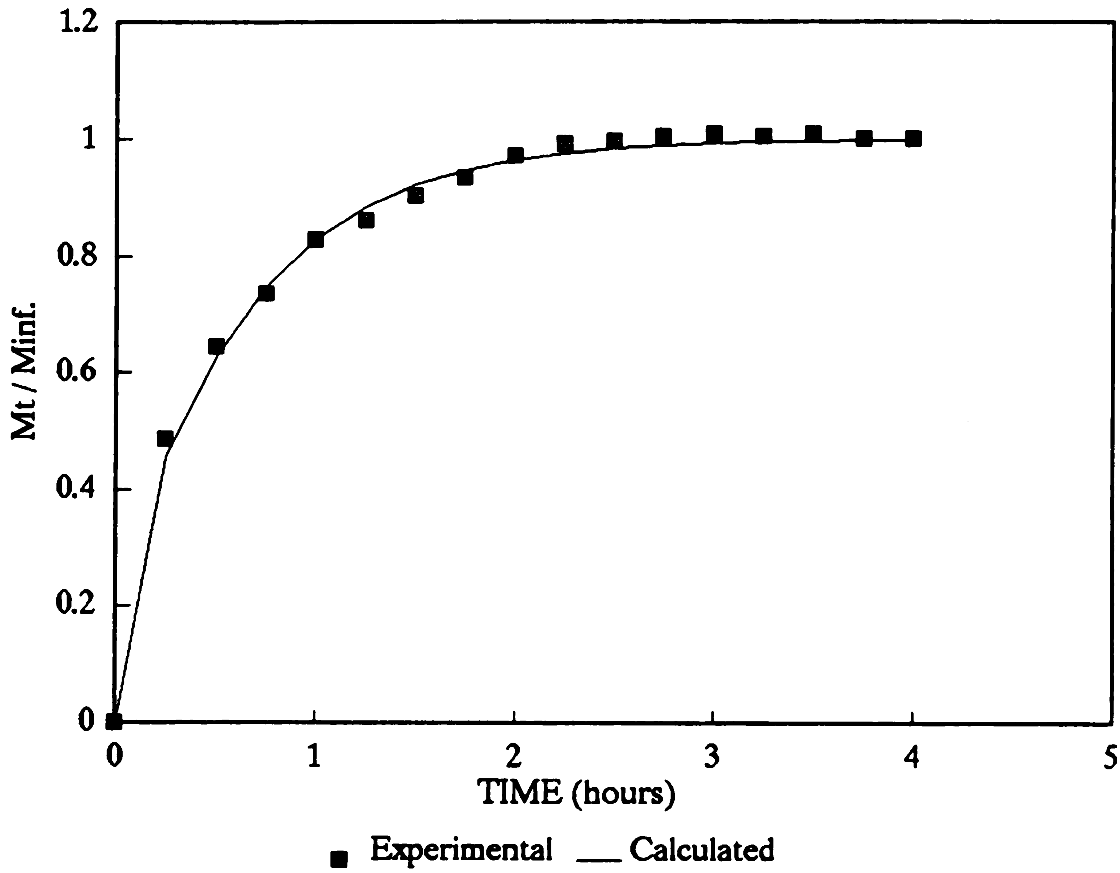

Figure 17. Comparison of experimental and calculated M_t/M_∞ for Aclar film at 43.50 - 58% R.H. and 25.0 ° C

Table 7. Diffusion coefficient of packaging materials at R.H. conditions

Relative Humidity (%)	Diffusion Coefficient (cm^2/sec.)
PVC Film - 7.5 mils	
0 - 26.90	5.58 E -09
58.20 - 77	4.5 E -09
Average	5.04 E -09
Aclar Film - 1.6 mils	
27.35 - 43.50	3.36 E -10
43.50 - 58	7.03 E -10
Average	5.195 E -10

Sorption Isotherm Model for the Tablet

The GAB (Guggenheim-Anderson-de Boer) sorption isotherm model was used to fit the experimental isotherm data of the tablet obtained in the present study. The equation is given in Eq. (20) (Bizot, 1991).

$$W/W_m = C\ k\ A_w\ /\ (1 - k\ A_w)\ (1 - k\ A_w + C\ k\ A_w) \quad (20)$$

A_w is water activity, W is water content on a dry basis, W_m is water content corresponding to saturation of all primary adsorption sites by one water molecule (previously called the monolayer in BET theory), C is the Guggenheim constant = c'exp

$(H_1 - H_m)/R\ T$, H_q is total heat of sorption of the multilayers (which is different from the heat of condensation of pure water), H_m is total heat of sorption of the first layer on primary sites, k is a factor correcting properties of the multilayer molecules with respect to the bulk liquid [$k = k' \exp (H_1 - H_q)/R\ T$], and H_1 is the heat of condensation of pure water vapor.

This GAB model has been reported as a very good model for fitting sorption isotherms over a range of water activities. It also provides a means to evaluate the amount of water tightly bound by the primary adsorption sites (W_m).

Equation (20) can also be written in the following manner

$$A_w/W = \alpha A_w^2 + \beta A_w + \gamma \qquad (21)$$

where

$$\alpha = k / W_m\ [1/C - 1] \qquad (22)$$

$$\beta = 1 / W_m\ [1 - 2/C] \qquad (23)$$

$$\gamma = 1 / W_m\ C\ k \qquad (24)$$

and a regression (quadratic) can be conducted on experimental numbers. From Eq. (23)

$$W_m = 1 / \beta\ [1 - 2/C] \qquad (25)$$

and combining Eq. (22) and Eq. (23) gives the following equation.

$$\alpha = k\,\beta\ /\ [1 - 2/C]\quad [1/C - 1] \tag{26}$$

Eq. (24) and Eq. (25) provided

$$\gamma = \beta\ /\ [1 - 2/C]\ \ C\ k \tag{27}$$

which simplified to Eq. (28).

$$k = \beta\ /\ \gamma\ [C - 2] \tag{28}$$

From Eq. (26) and Eq. (28), Eq. (29) is defined.

$$\alpha = \beta^2\ (1 - C)\ /\ \gamma\ (C - 2)\ (C - 2) \tag{29}$$

The constants (GAB) were calculated to be

$\alpha = -1.79$

$\beta = 1.922$

$\gamma = 0.064$

and can be used in the above computations. The constants (α, β, and γ) were figured using matrices which consisted of combinations of X, X^2, X^3, X^4, Y, XY, X^2Y, and N. X was the summation of experimental A_w, Y was the summation of experimental A_w/EMC, and N was the number of experimental points. A plot of the experimental moisture sorption isotherm against the GAB model produced a very good fit of the two curves. This plot is found in Figure 18.

The quality of the fit can be analyzed from the result of

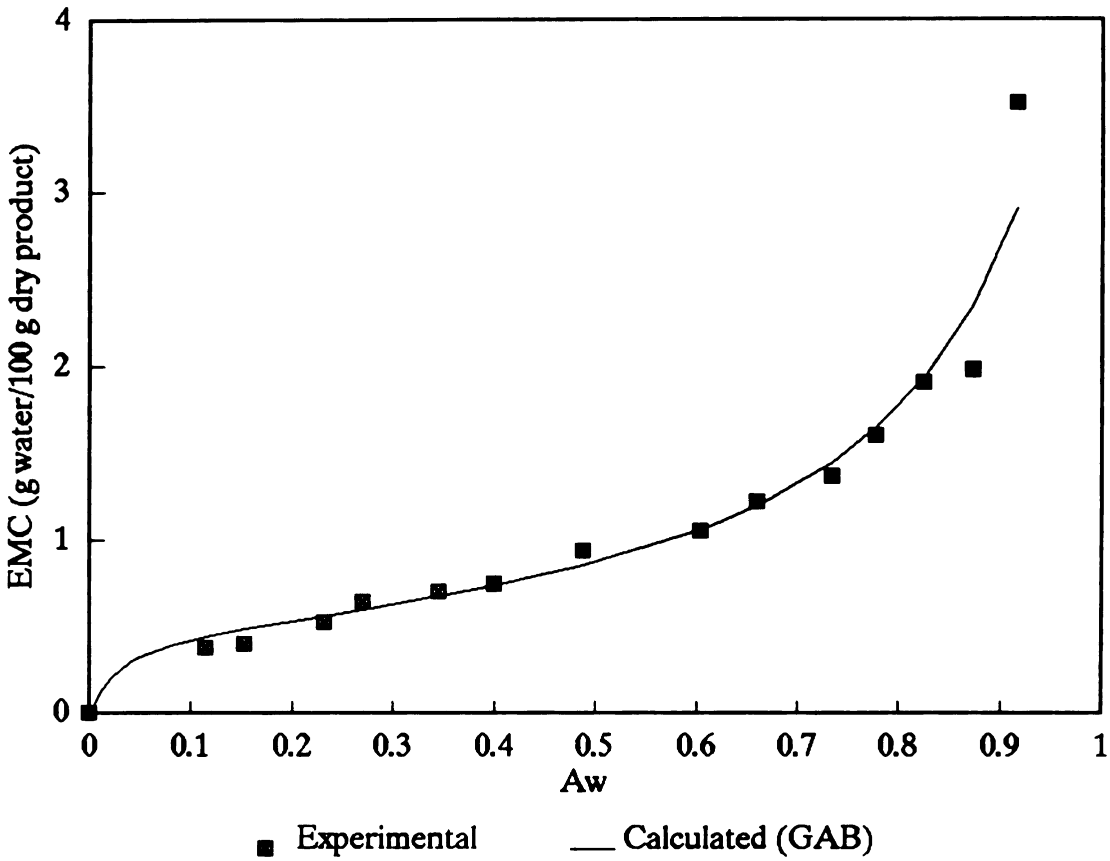

Figure 18. Plot of experimental moisture sorption isotherm and calculated GAB isotherm of 20 mg Deltasone tablet at 25.0 ° C

the relative percent root mean square (% RMS)

$$\% \text{ RMS} = \sqrt{[\Sigma (W_i - W_i^*/W_i)^2 / N]} \times 100 \tag{30}$$

where N is the number of experimental points, W_i is the experimental water content, and W_i^* is the calculated water content (Bizot, 1991). The RMS was calculated to be 11.11%, which verifies the strength of the fit for the experimental and calculated data.

Calculations of Package / Product Dimensions

There are four additional parameters of the packaging material and the pharmaceutical product which must be determined. They include the surface area of the tablet, the volume of the tablet, the surface area of the blister package, and the inner volume of the blister package. The surface area of the Deltasone tablet (A_T) is found by

$$A_T = 2 \pi R_T^2 \tag{31}$$

where R_T is the radius of the tablet. Likewise, the volume of the pharmaceutical tablet (V_T) is deduced from the following equation.

$$V_T = (\pi R_T^2) (T_T) \tag{32}$$

T_T is the tablet thickness. The surface area of the blister package (A_P) is as follows

$$A_P = \pi R_P^2 + 2 \pi R_P T_P \tag{33}$$

where R_P is the radius of the blister, and T_P is the height of the blister package. Lastly, the inner volume of the blister package (V_p) has the following calculation.

$$V_p = \pi R_p^2 T_p \tag{34}$$

For this project, the permeable blister package area did not include the aluminum foil backing, as it would be impermeable to moisture.

Other Parameters for Computer Program

The absolute humidity (A.H.) is a necessary component for the finite difference computer model since the driving of water is based on the absolute concentration of water through the system. The absolute humidity can be located from a psychrometric chart at saturation temperature.

$$C_{sat} = A.H. / 1.5829 T \tag{35}$$

C_{sat} is the concentration of water in the air at saturation (gram / ml) and T is in ° R.

Henry's Law Constant needed to be determined as well using different units as those described by Eq. (9) with the following equation.

$$C_{LE} = H_L C_E \tag{36}$$

H_L is Henry's constant (g H_2O/cm^3 polymer) / (g H_2O/cm^3 air) and is dependent on packaging material and temperature. C_{LE} is the concentration of absorbed water vapor on the outer surface of the package (constant). C_E is the concentration of water vapor outside the package (constant).

Table 8 lists all of the experimental values which were used in this finite difference simulation computer model.

Moisture Uptake of Blister Package with Product

Over a several week period, the water uptake of the total 10 cavity blister package with tablets was monitored. Five samples were contained in an 80% R.H. condition, and five were also stored in a 90% R.H. condition at 22.2 ° C. Each container also held one empty 10 cavity blister package in order to factor in the moisture sorption of the packaging material alone. The percent moisture content of an individual tablet was calculated with the following equation

$$M.C. = [((a - b) / 10) / (W)] * 100 \qquad (37)$$

where W is the dry weight of the tablet, "a" is the weight of the filled blister package at any timepoint, and "b" is the weight of the empty blister package at the same timepoint. The results of this portion of the study are presented in Table 9 (80% R.H. level) and Table 10 (90% R.H. level), respectively. Graphical presentations are shown in Figures

Table 8. Values for use in simulation model

Variable	Value	Reference
Temperature (T)	25.0 ° Celsius	Given
Storage Relative Humidity (R.H.)	80%, 90%	Given
Absolute Humidity (A.H.)	0.0163, 0.0183 g H_2O/g Air	Equation (35)
Package Diffusion Coefficient (D_L)	0.02 E -07 cm^2/sec.	Equation (19)
Henry's Law Constant (H_L)	125.12	Equation (36)
Package Thickness (L)	0.023, 0.0114 cm	Measured
Blister Surface Area (A_P)	3.78 cm^2	Equation (33)
Blister Volume (V_P)	0.80 cm^3	Equation (34)
Number of Package Layers (L)	5	Selected
Tablet Diffusion Coefficient (D_R)	0.1179 E -05 cm^2/sec.	Equation (16)
Initial Moisture Content (IMC)	$\frac{0.0001 \text{ g } H_2O}{100 \text{ g dry product}}$	Estimated
Critical Moisture Content (CMC)	$\frac{2.0 \text{ g } H_2O}{100 \text{ g dry product}}$	Selected
Dry Tablet Weight (W)	0.4077 g	Measured
Tablet Radius (R_T)	0.50 cm	Measured
Tablet Thickness (T_T)	0.392 cm	Measured
G.A.B. Constant α	-1.79	Equation (22)
G.A.B. Constant β	1.922	Equation (23)
G.A.B. Constant γ	0.064	Equation (24)
Number of Shells (U)	5	Selected

* H_L has units of (g H_2O/cm^3 PKG) / (g H_2O/cm^3 Air)

19 and 20.

Tables 9 and 10 give the moisture gain for each of the five sample blister packages and the empty control sample over time for each environmental condition. The average moisture gain and standard deviation of these packages are also provided. The average moisture content per tablet calculated using Eq. (37) is tabulated and plotted. It is apparent from the standard deviation that there is variability among the samples for moisture uptake. All blister packs did show a steady increase in mass over the duration.

Figure 21 and Figure 22 compare the experimental packaged tablet moisture content curves with the curves generated by the shelf life simulation model using a finite difference method at 80 and 90% R.H., respectively. For these figures, the blister laminate thickness used in the computer program was 9.1 mils, which was the thickness of the flat sheet material. In addition, the program was tested with a package thickness of 4.5 mils, which was the measured value for the formed blister. The comparative results are available in Figures 23 and 24. With the decrease in thickness, there were significant variations between the experimental and calculated data.

Table 9. Moisture gain of complete blister package with tablets at 80% R.H. and 22.2 deg. C

Moisture Gain of 10 Cavity Blister Samples with 10 Tablets (grams)

TIME (weeks)	EMPTY (Control)	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	AVERAGE	STD. DEV.	AVERAGE MOISTURE CONTENT PER TABLET (%)
0		0	0	0	0	0	0	0	0
1		0.0062	0.004	0.0036	0.0058	0.0089	0.0057	0.001887	0.139809
2		0.0122	0.0094	0.011	0.0119	0.0177	0.01244	0.002805	0.305126
3	0	0.0173	0.0195	0.0175	0.0138	0.0241	0.01844	0.003373	0.452293
4.29	0.002	0.0219	0.0233	0.0345	0.0216	0.0322	0.0267	0.005508	0.605838
6.57	0	0.0256	0.0217	0.0242	0.0312	0.0277	0.02608	0.003218	0.639686
7.57	0	0.0284	0.031	0.024	0.0291	0.0284	0.02818	0.002296	0.691195
9.57	0.003	0.0363	0.0398	0.0383	0.035	0.0354	0.03696	0.001821	0.832965
17.57	0.0077	0.0392	0.0354	0.0477	0.0447	0.0432	0.04204	0.004304	0.842286
39.57	0.0143	0.0647	0.0453	0.0679	0.0527	0.0772	0.06156	0.011292	1.159186

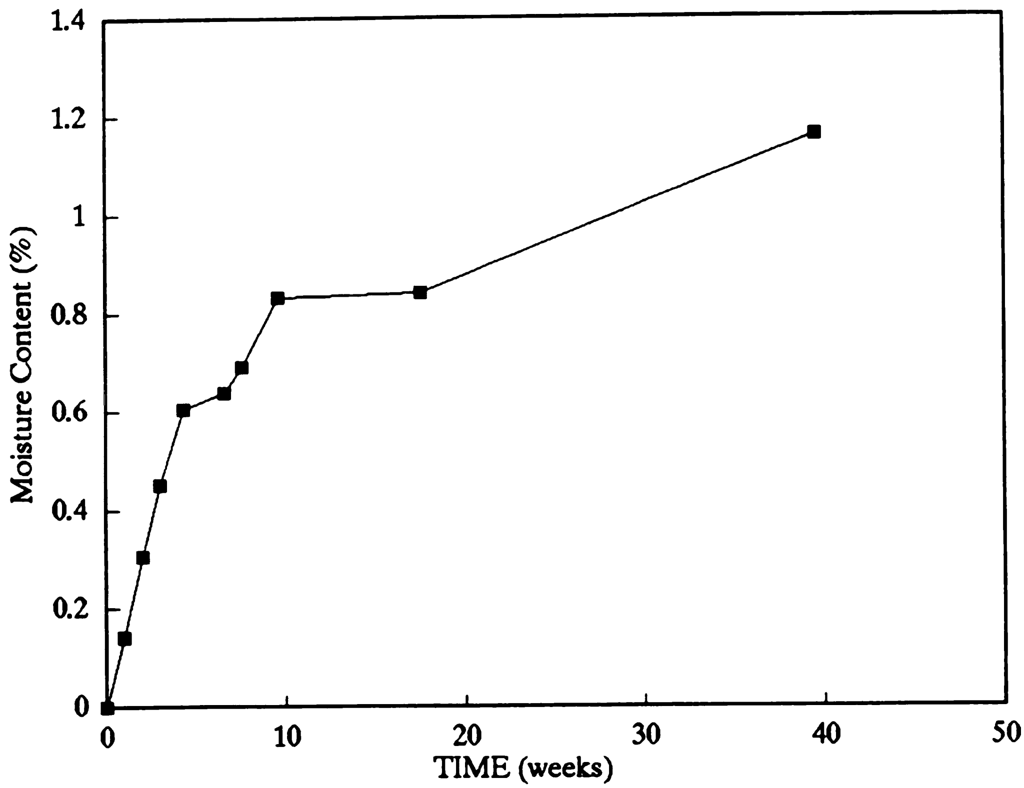

Figure 19. Moisture content of tablets in blisters at 22.2 ° C and 80% R.H.

Table 10. Moisture gain of complete blister package with tablets at 90% R.H. and 22.2 deg. C

Moisture Gain of 10 Cavity Blister Samples with 10 Tablets (grams)

TIME (weeks)	EMPTY (Control)	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	AVERAGE	STD. DEV.	AVERAGE MOISTURE CONTENT PER TABLET (%)
0		0	0	0	0	0	0	0	0
1		0.0074	0.0124	0.0072	0.0094	0.0076	0.0088	0.001964	0.215845
2		0.0074	0.0163	0.0092	0.0204	0.0102	0.0127	0.004875	0.311504
3	0	0.0109	0.0202	0.0133	0.023	0.015	0.01648	0.004467	0.404219
4.29	0.001	0.0265	0.0188	0.0178	0.0177	0.0153	0.01922	0.003818	0.446897
6.57	0.0032	0.0244	0.0304	0.035	0.0462	0.0303	0.03326	0.007293	0.737307
7.57	0.006	0.0324	0.0365	0.0366	0.0385	0.0385	0.0365	0.002228	0.748099
9.57	0.0076	0.0356	0.0515	0.0364	0.0512	0.0404	0.04302	0.006994	0.868776
13.86	0.0044	0.0403	0.0407	0.0611	0.0488	0.0558	0.04934	0.008206	1.102281
43.57	0.0376	0.1136	0.098	0.0733	0.0827	0.0714	0.0878	0.015968	1.231298

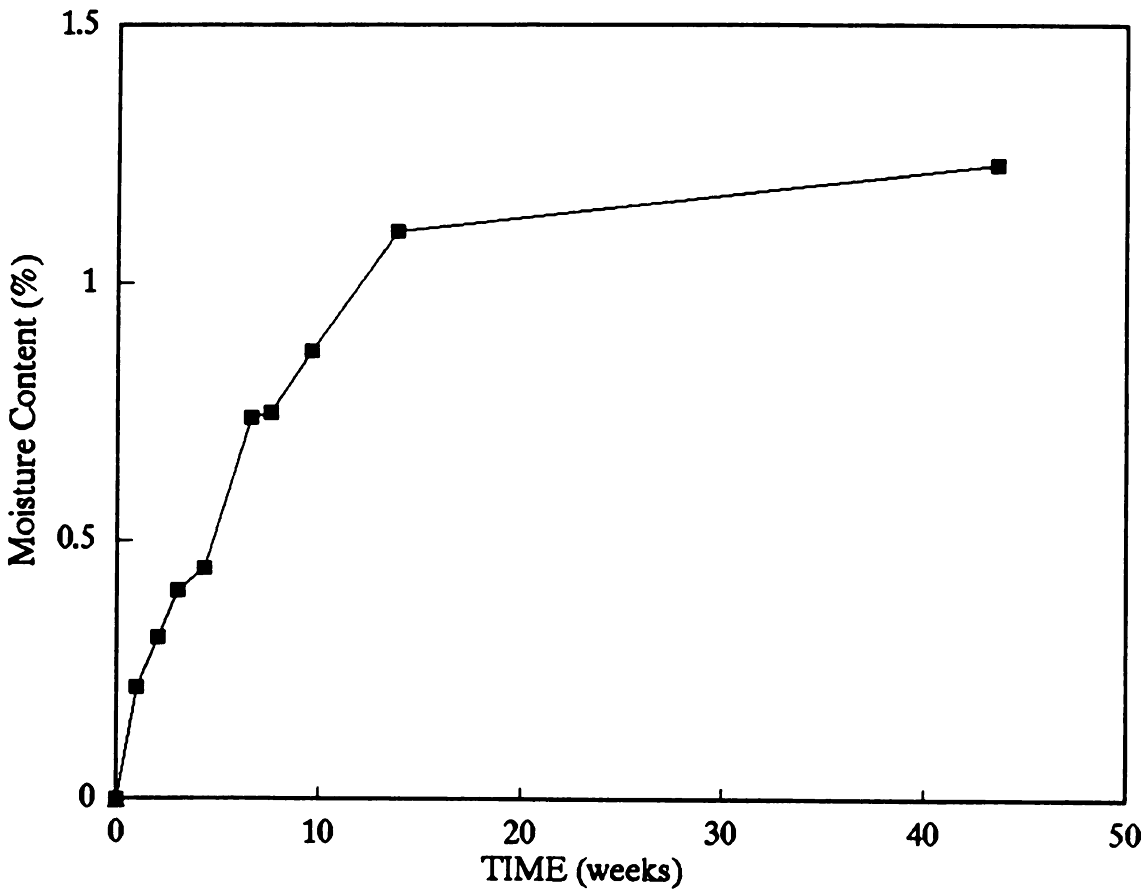

Figure 20. Moisture content of tablets in blisters at 22.2 ° C and 90% R.H.

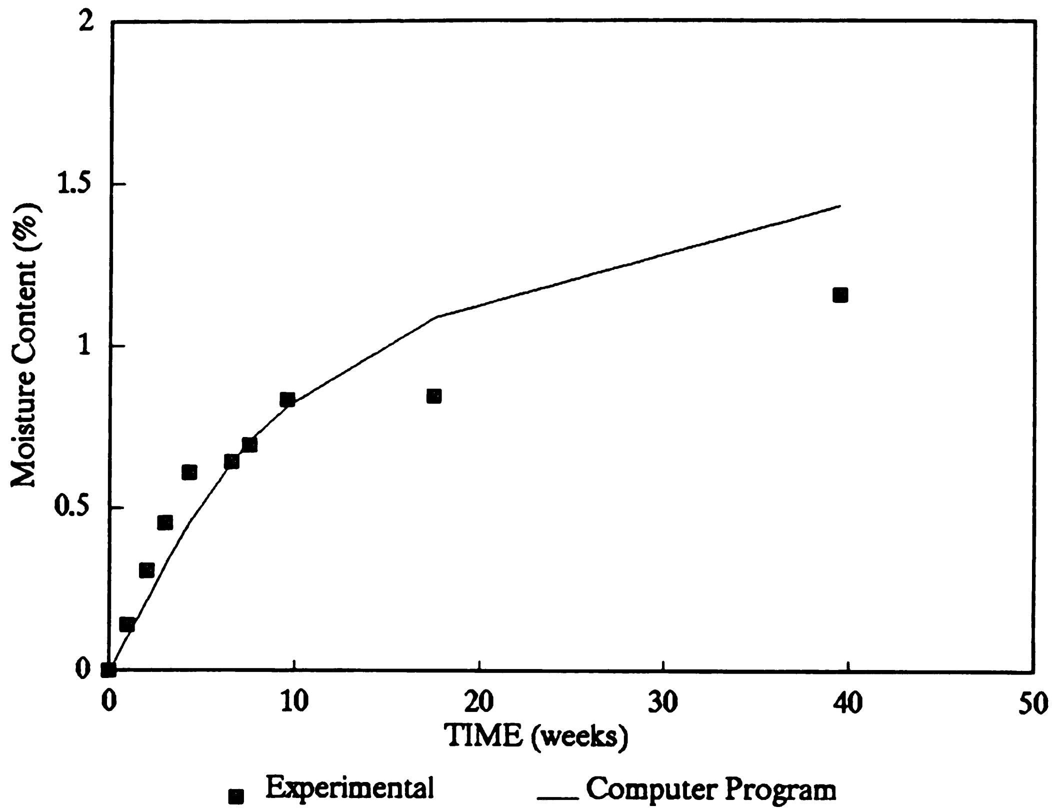

Figure 21. Moisture content of tablets in blisters at 22.2 ° C and 80% R.H. for experimental and computer program data

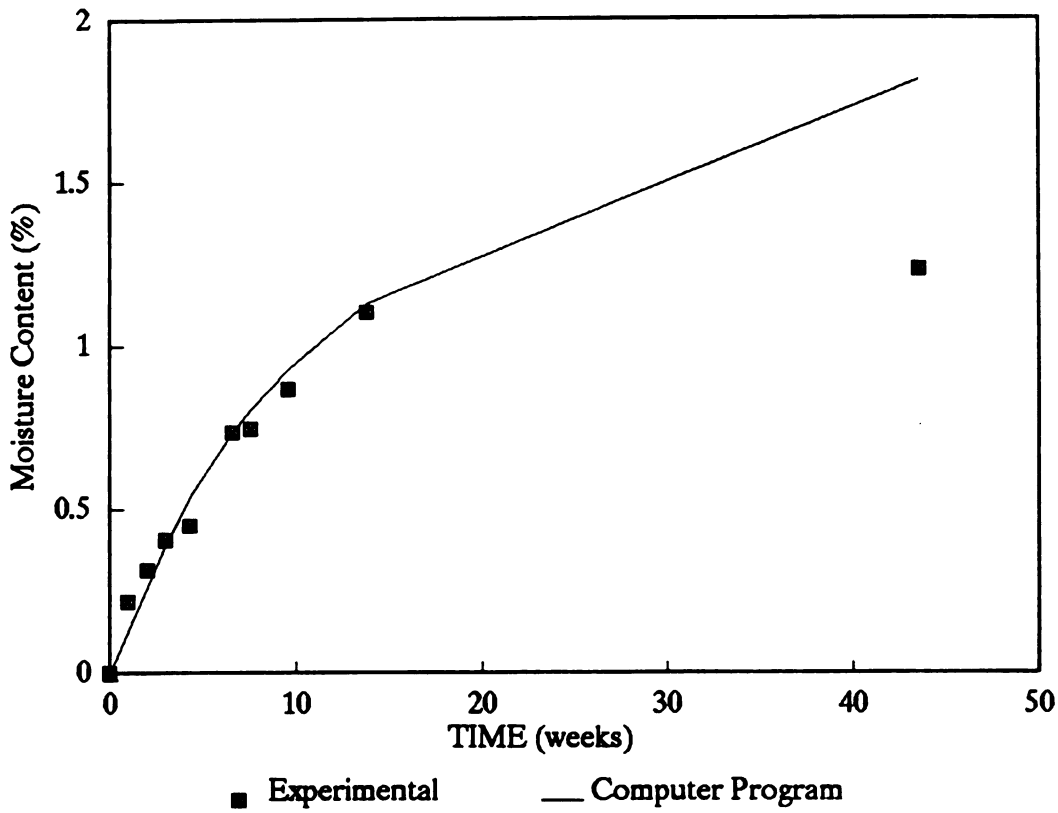

Figure 22. Moisture content of tablets in blisters at 22.2 ° C and 90% R.H. for experimental and computer program data

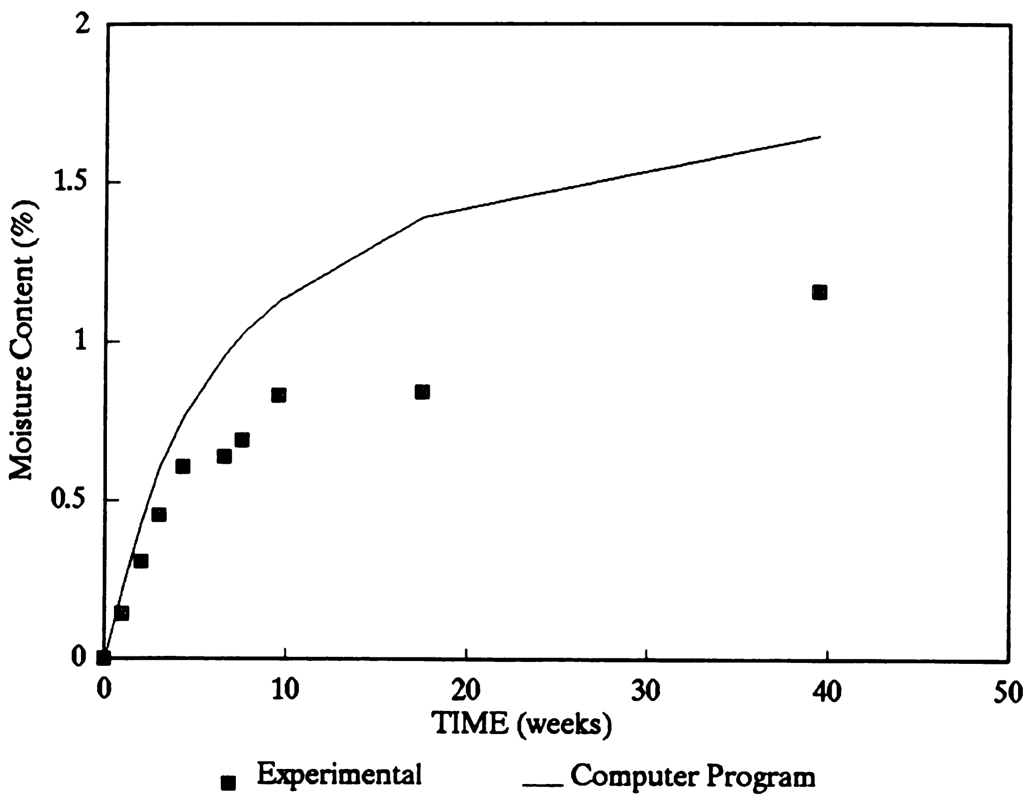

Figure 23. Moisture content of tablets in blisters at 22.2 ° C and 80% R.H. for experimental and computer program data (4.5 mils thickness)

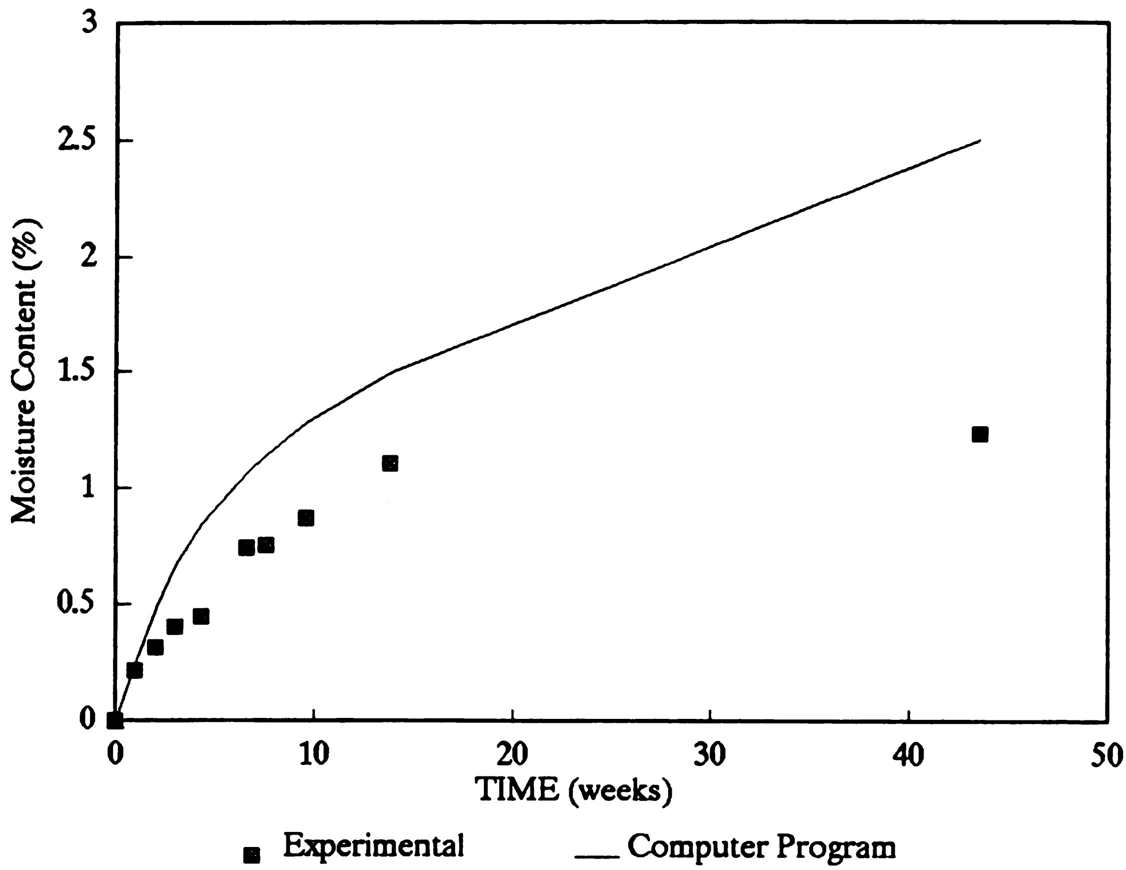

Figure 24. Moisture content of tablets in blisters at 22.2 ° C and 90% R.H. for experimental and computer program data (4.5 mils thickness)

ERROR ANALYSIS

Throughout the process of performing this research-based project, there were many opportunities to introduce both operator and machine error. Errors are possible even in the most controlled situations. For example, the relative humidity produced within the hangdown tube of the electrobalance, where the sample was located, was dependent on both the humidity sensors (hygrosensors) and the hygrometer unit used. The hygrometer and hygrosensors had been calibrated, but there may have been some error of approximately +/- 1%.

Secondly, there were a few instances when the light in the chamber where the hangdown tube was located was left on causing a potential temperature fluctuation of +/- 1-2 ° C. This increased heat in the chamber could have resulted in some changes in the tablet weight gain during the creation of the sorption isotherm. The extra heat in the chamber decreased the relative humidity for a short period of time.

Another error in relative humidity could have occurred inside of the five gallon buckets containing the salt solutions. Therefore, there could be a greater or lesser weight gain over time due to this inaccuracy of about 4-5%. Also, temperature variations could have existed in the storage location of +/- 2-3 $^{\circ}$ C.

It is uncertain whether or not the Deltasone pharmaceutical tablet was thoroughly dried to 0% moisture content at the onset of this experiment. However, initial desorption studies showed that the product had reached equilibrium during the nitrogen flush.

Lastly, calibration of the electrobalance could have been inaccurately performed with the calibration weights. This calibration occurs before the sample product is put into the hangdown tube. Calibration weights are placed in the sample dish for a specified period of time for the process to take place.

CONCLUSIONS

Comparison Between Calculated Data and Validation Experiment

A finite difference computer program for shelf life simulation calculated the shelf life of the 20 mg Deltasone tablet packaged in such a way as described in this research project, using the values in Table 8. This simulation program estimated the shelf life to be 10,010 hours (417 days) under the conditions of 25.0 $^{\circ}$ C and 90% R.H. for a package thickness of 9.1 mils. This translates into a shelf life value of nearly 60 weeks. The finite difference program showed that at 25.0 $^{\circ}$ C and 80% R.H., the product would not reach the critical moisture content of 2.0 g H_2O/100 g dry product from an initial moisture content of 0.0001 g H_2O/100 g dry product. This occurs since the equilibrium moisture content at 80% R.H. is less than 2.0 g H_2O/100 g dry product from the sorption isotherm in Figure 18. For this case, the maximum value for the moisture content came out to be 1.5477 g H_2O/100 g dry product at 9,200 hours (383 days). Through several trials using the model, it was evident that the value of the dimensionless constants, Q and G, played a key role in the stability of the computational process (see Appendix A).

When compared to the experimental blister packages which were stored at 80% R.H., the program agreed quite well with the data, when the packaging film thickness used was 9.1 mils. For example, when the EMC reached 0.6412 g H_2O/100 g dry product, the shelf life was calculated to be 6.6 weeks from the finite difference program. The experimental data of the packaged product found the shelf life to be 6.6 weeks at a moisture content of 0.64 g H_2O/100 g dry product. This can be seen in Figure 21. In addition, the 90% R.H. condition had satisfactory agreement with the shelf life simulation model, when using a value for the package thickness of 9.1 mils. This program computed a shelf life of 13.9 weeks at an EMC of 1.1321 g H_2O/100 g dry product. Experimental data at 90% R.H. revealed a shelf life of 13.9 weeks at 1.1023 g H_2O/100 g dry product. Also, this is expressed in Figure 22. The input/output results of the computer program with all of the data can be found in Appendix A.

It was found that the formed blister structure of PVC and Aclar had a package thickness close to 4.5 mils, as seen in Figure 1. An assumption was made that the two laminated materials are proportionally formed during the blister manufacturing process in relation to the original unformed film sheet (9.1 mils). At this value of 4.5 mils, the finite difference program computed changes in moisture content over time which far exceeded the experimental data. This deviation became more pronounced with an increase in time. There could be several reasons for these results. The relative humidity in the buckets could have been decreasing over time causing less moisture to be gained in later weeks. On the other hand, this computer program for the prediction of shelf life may be overestimating the moisture content of this product. In addition, this program was designed for single layer packaging materials.

RECOMMENDATIONS FOR FUTURE WORK

A recommendation for future work in this area of mathematical modeling and shelf life prediction for packaged food and pharmaceutical products would include some research into a program which could evaluate multi-layer packaging films. In addition, another interesting project for further development would be an expansion of the shelf life program using the finite difference method to analyze other packaging containers. Currently, the focus of this model is blister packaging, but could possibly also involve bottles with closures and bulk materials, such as boxes or lined fiber drums. This type of predictive model could have value for the pharmaceutical industry as various package configurations need to be considered. Ideally, a program with the capabilities to advise on product quantity per container based on product size, available headspace and product characteristics would be a useful tool.

Another addition to a shelf life model might be the incorporation of oxygen transmission rates through a package component, which can also cause product degradation. A program which integrates all environmental conditions surrounding a product/package system would have great benefit.

APPENDICES

APPENDIX A

APPENDIX A

Program Stability Given Q Value, Input/Output Data Sheets

This finite difference computer program uses a number of dimensionless constants as part of the computation of the shelf life. The dimensionless constant, Q, was of particular interest while running various trials with this model. According to Kim (1992), Q is used to solve the diffusion equation of the packaging material to moisture. In any application of this program, Q must be less than 0.5 in order to avoid a negative concentration value using (1-2Q). Q is also dependent on the geometry of the product under investigation.

With the data generated for this project, Q needed to be determined by trial and error as to the optimum value for use. It was found that an appropriate Q constant for the data was between 0.001 and 0.00142. It was apparent that as the critical moisture content increased, Q needed to decrease. In addition, Q affects G, another dimensionless constant, which must be less than 0.3 for purposes of numerical stability (Kim, 1992).

All input and output data used from the computer program are found in the following section.

Computer Program Input/Output Data

```
 All data are checked successfully !!!
 Re-check all data entered
 -----------------------------------------------------------------
Temperature of storage environment incelsius =25.00
Relative humidity of storage environment in % =80.00
Absolute humidity of storage environment ingH20/gAir =.0163
Diffusion coefficient of packaging materialin 10^-7 cm^2/sec =0.020
Henry constant of packaging material in(gH2O/cm^3 PKG)/(gH2O/cm^3 Air) =    125.12
 000
Thickness of packaging material in cm =   0.01140
Surface area of packaging material in cm^2 =   3.78000
Volume of packaging material in cm^3 =   0.80000
Diffusion coefficient of product in 10^-5cm^2/sec =   0.11790
Initial moisture content in gH2O/100g dryproduct =0.00
Critical moisture content in gH2O/100g dryproduct =2.00
Dry weight of product in g =    0.40770
Chemical reaction rate =   0.0
Chemical reaction order =   0.0
Aw/M=-.1790E+01 Aw^2 + 0.1922E+01 Aw+ 0.6400E-01
Radius of product in cm =   0.50000
Thickness of product (Only Plate shape) incm =   0.39200
 ----------------------------------------------------------------------
            Hit any key to continue.....
 ----------------------------------------------------------------------
 INITIAL CONCENTRATION
 ----------------------------------------------------------------------
Concentration of outside environment (CE) =  0.01534  g/L
Concentration of outside surface of PKG(CLE) =  1.91945  g/L
Concentration of inside surface of PKG(CLH) =  0.00002  g/L
Concentration of headspace (CH) =  0.00000  g/L
Concentration of outside surface of product(CRH) =  0.00132  g/L
 ---------------------------------------------------------------------
 DIMENSSIONLESS CONSTANT
 ---------------------------------------------------------------------
Q=0.1420E-02
G=0.1520E-02
A1=0.1822E-04
B1=0.1902E-03
S=0.1981E+01
X=0.9000E+03
 =    7
 ---------------------------------------------------------------------
           Hit any key to continue ......
 ---------------------------------------------------------------------
    Enter the number of time to calculateconcentrations at once.

         <NOTICE !!!  It must be over 200 and be times of 200>
 ----------------------------------------------------------------------
```

(Plate Shape)
Each step is 152000. steps (83.6379hrs)
<# of the divided shell of product is 5

CLE	CL1	CL2	CL3	CL4	CLH	CH	Meq
CRH	CR1	CR2	CR3	CR4	CRC	GAIN	TIME(hrs)
1.9194	1.6483	1.3771	1.1060	0.8349	0.5639	0.2930	0.0222
0.0002	0.1134						
1.5014	1.4755	1.4560	1.4430	1.4366	1.4366	0.1100	83.6379
1.9194	1.6535	1.3877	1.1219	0.8562	0.5906	0.3252	0.0600
0.0005	0.2253						
2.9841	2.9587	2.9397	2.9270	2.9206	2.9206	0.2220	167.2758
1.9194	1.6635	1.4076	1.1518	0.8962	0.6409	0.3858	0.1312
0.0010	0.3340						
4.4225	4.3981	4.3799	4.3677	4.3616	4.3616	0.3307	250.9138
1.9194	1.6827	1.4460	1.2096	0.9736	0.7380	0.5030	0.2686
0.0021	0.4361						
5.7747	5.7523	5.7355	5.7243	5.7186	5.7186	0.4331	334.5517
1.9194	1.7114	1.5036	1.2960	1.0888	0.8822	0.6763	0.4713
0.0038	0.5274						
6.9836	6.9640	6.9493	6.9395	6.9346	6.9346	0.5248	418.1896
1.9194	1.7402	1.5612	1.3823	1.2039	1.0259	0.8485	0.6719
0.0054	0.6063						
8.0291	8.0122	7.9996	7.9911	7.9869	7.9869	0.6041	501.8275
1.9194	1.7638	1.6083	1.4530	1.2980	1.1434	0.9892	0.8356
0.0067	0.6746						
8.9334	8.9187	8.9077	8.9004	8.8967	8.8967	0.6727	585.4654
1.9194	1.7824	1.6455	1.5087	1.3721	1.2359	1.1000	0.9646
0.0077	0.7344						
9.7256	9.7127	9.7030	9.6965	9.6933	9.6933	0.7327	669.1033
1.9194	1.7972	1.6750	1.5530	1.4311	1.3095	1.1881	1.0672
0.0085	0.7876						
10.4292	10.4177	10.4090	10.4032	10.4003	10.4003	0.7860	752.7413
1.9194	1.8092	1.6990	1.5889	1.4789	1.3692	1.2597	1.1505
0.0092	0.8353						
11.0615	11.0510	11.0432	11.0380	11.0354	11.0354	0.8339	836.3792
1.9194	1.8191	1.7188	1.6186	1.5185	1.4186	1.3189	1.2195
0.0097	0.8786						
11.6351	11.6256	11.6184	11.6137	11.6113	11.6113	0.8774	920.0171
1.9194	1.8275	1.7355	1.6437	1.5519	1.4603	1.3688	1.2776
0.0102	0.9182						
12.1596	12.1509	12.1443	12.1399	12.1378	12.1378	0.9171	1003.6550
1.9194	1.8346	1.7498	1.6651	1.5804	1.4959	1.4115	1.3273
0.0106	0.9547						
12.6424	12.6343	12.6283	12.6242	12.6222	12.6222	0.9536	1087.2930
1.9194	1.8408	1.7622	1.6836	1.6051	1.5267	1.4485	1.3704
0.0110	0.9884						
13.0892	13.0817	13.0761	13.0724	13.0705	13.0705	0.9874	1170.9308
1.9194	1.8462	1.7730	1.6998	1.6267	1.5537	1.4808	1.4081
0.0113	1.0198						
13.5046	13.4976	13.4924	13.4889	13.4872	13.4872	1.0189	1254.5687
1.9194	1.8510	1.7825	1.7141	1.6458	1.5775	1.5094	1.4414
0.0115	1.0491						
13.8924	13.8859	13.8810	13.8778	13.8762	13.8762	1.0482	1338.2067
1.9194	1.8552	1.7911	1.7269	1.6628	1.5988	1.5349	1.4710
0.0118	1.0765						
14.2557	14.2496	14.2450	14.2420	14.2405	14.2405	1.0757	1421.8446
1.9194	1.8591	1.7987	1.7384	1.6781	1.6178	1.5577	1.4977
0.0120	1.1023						

14.5971	14.5913	14.5870	14.5841	14.5827	14.5827	1.1015	1505.4825
1.9194	1.8625	1.8056	1.7487	1.6918	1.6351	1.5783	1.5217
0.0122	1.1266						
14.9187	14.9132	14.9092	14.9065	14.9051	14.9051	1.1259	1589.1204
1.9194	1.8656	1.8118	1.7581	1.7043	1.6507	1.5971	1.5435
0.0123	1.1495						
15.2223	15.2172	15.2134	15.2108	15.2095	15.2095	1.1488	1672.7583
1.9194	1.8685	1.8175	1.7666	1.7157	1.6649	1.6141	1.5634
0.0125	1.1712						
15.5097	15.5048	15.5012	15.4988	15.4976	15.4976	1.1706	1756.3962
1.9194	1.8711	1.8228	1.7745	1.7262	1.6780	1.6298	1.5817
0.0126	1.1918						
15.7822	15.7775	15.7741	15.7718	15.7706	15.7706	1.1912	1840.0342
1.9194	1.8735	1.8276	1.7817	1.7358	1.6900	1.6442	1.5985
0.0128	1.2113						
16.0409	16.0365	16.0333	16.0311	16.0300	16.0300	1.2108	1923.6721
1.9194	1.8757	1.8320	1.7883	1.7447	1.7010	1.6575	1.6139
0.0129	1.2299						
16.2870	16.2829	16.2798	16.2777	16.2766	16.2766	1.2294	2007.3101
1.9194	1.8778	1.8361	1.7945	1.7529	1.7113	1.6698	1.6283
0.0130	1.2476						
16.5215	16.5175	16.5146	16.5126	16.5116	16.5116	1.2471	2090.9480
1.9194	1.8797	1.8399	1.8002	1.7605	1.7208	1.6812	1.6416
0.0131	1.2645						
16.7451	16.7413	16.7385	16.7366	16.7357	16.7357	1.2640	2174.5859
1.9194	1.8815	1.8435	1.8055	1.7676	1.7297	1.6918	1.6540
0.0132	1.2806						
16.9587	16.9550	16.9523	16.9505	16.9496	16.9496	1.2802	2258.2236
1.9194	1.8831	1.8468	1.8105	1.7742	1.7380	1.7018	1.6656
0.0133	1.2961						
17.1628	17.1593	17.1567	17.1550	17.1542	17.1542	1.2956	2341.8616
1.9194	1.8847	1.8499	1.8152	1.7804	1.7457	1.7111	1.6764
0.0134	1.3108						
17.3582	17.3548	17.3524	17.3507	17.3499	17.3499	1.3104	2425.4995
1.9194	1.8861	1.8528	1.8195	1.7863	1.7530	1.7198	1.6866
0.0135	1.3249						
17.5453	17.5421	17.5397	17.5381	17.5373	17.5373	1.3245	2509.1375
1.9194	1.8875	1.8556	1.8236	1.7917	1.7598	1.7280	1.6962
0.0136	1.3385						
17.7246	17.7216	17.7193	17.7178	17.7170	17.7170	1.3381	2592.7754
1.9194	1.8888	1.8581	1.8275	1.7969	1.7663	1.7357	1.7052
0.0136	1.3515						
17.8967	17.8938	17.8916	17.8902	17.8894	17.8894	1.3511	2676.4133
1.9194	1.8900	1.8606	1.8311	1.8017	1.7723	1.7430	1.7136
0.0137	1.3640						
18.0620	18.0592	18.0571	18.0557	18.0550	18.0550	1.3636	2760.0510
1.9194	1.8911	1.8629	1.8346	1.8063	1.7780	1.7498	1.7216
0.0138	1.3759						
18.2208	18.2181	18.2161	18.2147	18.2140	18.2140	1.3756	2843.6892
1.9194	1.8922	1.8650	1.8378	1.8106	1.7835	1.7563	1.7292
0.0138	1.3875						
18.3734	18.3708	18.3689	18.3676	18.3669	18.3669	1.3871	2927.3269
1.9194	1.8933	1.8671	1.8409	1.8147	1.7886	1.7625	1.7364
0.0139	1.3986						
18.5203	18.5178	18.5159	18.5147	18.5141	18.5141	1.3982	3010.9651
1.9194	1.8942	1.8690	1.8438	1.8186	1.7934	1.7683	1.7432
0.0139	1.4092						
18.6617	18.6593	18.6575	18.6563	18.6557	18.6557	1.4089	3094.6028
1.9194	1.8952	1.8709	1.8466	1.8223	1.7981	1.7738	1.7496
0.0140	1.4195						

18.7979	18.7956	18.7938	18.7927	18.7921	18.7921	1.4192	3178.2407
1.9194	1.8960	1.8726	1.8492	1.8258	1.8025	1.7791	1.7558
0.0140	1.4294						
18.9291	18.9269	18.9252	18.9241	18.9235	18.9235	1.4291	3261.8787
1.9194	1.8969	1.8743	1.8517	1.8292	1.8066	1.7841	1.7616
0.0141	1.4390						
19.0557	19.0535	19.0519	19.0508	19.0503	19.0503	1.4387	3345.5166
1.9194	1.8977	1.8759	1.8541	1.8323	1.8106	1.7889	1.7672
0.0141	1.4482						
19.1777	19.1756	19.1741	19.1730	19.1725	19.1725	1.4479	3429.1545
1.9194	1.8984	1.8774	1.8564	1.8354	1.8144	1.7934	1.7725
0.0142	1.4571						
19.2955	19.2935	19.2920	19.2910	19.2905	19.2905	1.4568	3512.7925
1.9194	1.8991	1.8788	1.8586	1.8383	1.8180	1.7978	1.7775
0.0142	1.4657						
19.4092	19.4073	19.4058	19.4049	19.4044	19.4044	1.4654	3596.4302
1.9194	1.8998	1.8802	1.8606	1.8410	1.8215	1.8019	1.7824
0.0142	1.4740						
19.5190	19.5172	19.5158	19.5148	19.5144	19.5144	1.4737	3680.0684
1.9194	1.9005	1.8816	1.8626	1.8437	1.8248	1.8059	1.7870
0.0143	1.4820						
19.6252	19.6233	19.6220	19.6211	19.6206	19.6206	1.4818	3763.7061
1.9194	1.9011	1.8828	1.8645	1.8462	1.8279	1.8096	1.7914
0.0143	1.4897						
19.7277	19.7260	19.7247	19.7238	19.7233	19.7233	1.4895	3847.3442
1.9194	1.9017	1.8840	1.8663	1.8486	1.8309	1.8133	1.7956
0.0144	1.4972						
19.8269	19.8252	19.8239	19.8231	19.8227	19.8227	1.4970	3930.9819
1.9194	1.9023	1.8852	1.8681	1.8509	1.8338	1.8167	1.7997
0.0144	1.5045						
19.9228	19.9211	19.9199	19.9191	19.9187	19.9187	1.5043	4014.6201
1.9194	1.9029	1.8863	1.8697	1.8532	1.8366	1.8201	1.8036
0.0144	1.5115						
20.0156	20.0140	20.0128	20.0120	20.0116	20.0116	1.5113	4098.2578
1.9194	1.9034	1.8874	1.8713	1.8553	1.8393	1.8233	1.8073
0.0144	1.5183						
20.1054	20.1038	20.1027	20.1019	20.1015	20.1015	1.5181	4181.8960
1.9194	1.9039	1.8884	1.8729	1.8573	1.8418	1.8263	1.8109
0.0145	1.5248						
20.1923	20.1908	20.1897	20.1889	20.1886	20.1886	1.5246	4265.5337
1.9194	1.9044	1.8894	1.8743	1.8593	1.8443	1.8293	1.8143
0.0145	1.5312						
20.2764	20.2750	20.2739	20.2732	20.2728	20.2728	1.5310	4349.1719
1.9194	1.9049	1.8903	1.8758	1.8612	1.8466	1.8321	1.8176
0.0145	1.5373						
20.3579	20.3566	20.3555	20.3548	20.3545	20.3545	1.5372	4432.8096
1.9194	1.9053	1.8912	1.8771	1.8630	1.8489	1.8348	1.8208
0.0146	1.5433						
20.4369	20.4356	20.4346	20.4339	20.4335	20.4335	1.5431	4516.4473
1.9194	1.9058	1.8921	1.8784	1.8648	1.8511	1.8374	1.8238
0.0146	1.5491						
20.5134	20.5121	20.5112	20.5105	20.5102	20.5102	1.5489	4600.0854
1.9194	1.9062	1.8929	1.8797	1.8664	1.8532	1.8400	1.8267
0.0146	1.5547						
20.5876	20.5863	20.5854	20.5848	20.5844	20.5844	1.5545	4683.7231
1.9194	1.9066	1.8937	1.8809	1.8681	1.8552	1.8424	1.8296
0.0146	1.5601						
20.6595	20.6583	20.6574	20.6567	20.6564	20.6564	1.5599	4767.3613
1.9194	1.9070	1.8945	1.8821	1.8696	1.8572	1.8447	1.8323
0.0146	1.5654						

20.7292	20.7280	20.7271	20.7265	20.7262	20.7262	1.5652	4850.9990
1.9194	1.9074	1.8953	1.8832	1.8711	1.8590	1.8470	1.8349
0.0147	1.5705						
20.7968	20.7957	20.7948	20.7942	20.7939	20.7939	1.5703	4934.6372
1.9194	1.9077	1.8960	1.8843	1.8726	1.8608	1.8491	1.8374
0.0147	1.5754						
20.8624	20.8613	20.8604	20.8599	20.8596	20.8596	1.5753	5018.2749
1.9194	1.9081	1.8967	1.8853	1.8739	1.8626	1.8512	1.8399
0.0147	1.5802						
20.9260	20.9249	20.9241	20.9236	20.9233	20.9233	1.5801	5101.9126
1.9194	1.9084	1.8974	1.8863	1.8753	1.8643	1.8532	1.8422
0.0147	1.5849						
20.9878	20.9867	20.9859	20.9854	20.9851	20.9851	1.5848	5185.5508
1.9194	1.9087	1.8980	1.8873	1.8766	1.8659	1.8552	1.8445
0.0147	1.5894						
21.0477	21.0467	21.0459	21.0454	21.0451	21.0451	1.5893	5269.1890
1.9194	1.9090	1.8986	1.8882	1.8778	1.8675	1.8571	1.8467
0.0148	1.5938						
21.1059	21.1049	21.1041	21.1036	21.1034	21.1034	1.5937	5352.8267
1.9194	1.9093	1.8992	1.8892	1.8791	1.8690	1.8589	1.8488
0.0148	1.5981						
21.1623	21.1614	21.1607	21.1602	21.1599	21.1599	1.5980	5436.4644
1.9194	1.9096	1.8998	1.8900	1.8802	1.8704	1.8606	1.8509
0.0148	1.6022						
21.2172	21.2162	21.2155	21.2151	21.2148	21.2148	1.6021	5520.1021
1.9194	1.9099	1.9004	1.8909	1.8814	1.8718	1.8623	1.8528
0.0148	1.6062						
21.2704	21.2695	21.2688	21.2684	21.2682	21.2682	1.6061	5603.7407
1.9194	1.9102	1.9009	1.8917	1.8824	1.8732	1.8640	1.8547
0.0148	1.6101						
21.3221	21.3213	21.3206	21.3202	21.3199	21.3199	1.6100	5687.3784
1.9194	1.9105	1.9015	1.8925	1.8835	1.8745	1.8656	1.8566
0.0148	1.6139						
21.3724	21.3715	21.3709	21.3705	21.3702	21.3702	1.6138	5771.0161
1.9194	1.9107	1.9020	1.8933	1.8845	1.8758	1.8671	1.8584
0.0149	1.6176						
21.4212	21.4204	21.4197	21.4193	21.4191	21.4191	1.6175	5854.6538
1.9194	1.9110	1.9025	1.8940	1.8855	1.8770	1.8686	1.8601
0.0149	1.6212						
21.4686	21.4678	21.4672	21.4668	21.4666	21.4666	1.6211	5938.2920
1.9194	1.9112	1.9030	1.8947	1.8865	1.8782	1.8700	1.8618
0.0149	1.6247						
21.5147	21.5139	21.5133	21.5130	21.5128	21.5128	1.6246	6021.9302
1.9194	1.9114	1.9034	1.8954	1.8874	1.8794	1.8714	1.8634
0.0149	1.6281						
21.5595	21.5588	21.5582	21.5578	21.5576	21.5576	1.6280	6105.5679
1.9194	1.9117	1.9039	1.8961	1.8883	1.8805	1.8727	1.8650
0.0149	1.6314						
21.6031	21.6023	21.6018	21.6014	21.6012	21.6012	1.6313	6189.2056
1.9194	1.9119	1.9043	1.8967	1.8892	1.8816	1.8740	1.8665
0.0149	1.6346						
21.6454	21.6447	21.6441	21.6438	21.6436	21.6436	1.6345	6272.8438
1.9194	1.9121	1.9047	1.8974	1.8900	1.8826	1.8753	1.8680
0.0149	1.6377						
21.6865	21.6858	21.6853	21.6850	21.6848	21.6848	1.6376	6356.4814
1.9194	1.9123	1.9051	1.8980	1.8908	1.8837	1.8765	1.8694
0.0149	1.6407						
21.7266	21.7259	21.7254	21.7250	21.7248	21.7248	1.6406	6440.1196
1.9194	1.9125	1.9055	1.8986	1.8916	1.8846	1.8777	1.8708
0.0150	1.6436						

21.7655	21.7648	21.7643	21.7640	21.7638	21.7638	1.6435	6523.7573
1.9194	1.9127	1.9059	1.8991	1.8924	1.8856	1.8788	1.8721
0.0150	1.6465						
21.8033	21.8027	21.8022	21.8018	21.8017	21.8017	1.6464	6607.3955
1.9194	1.9129	1.9063	1.8997	1.8931	1.8865	1.8800	1.8734
0.0150	1.6493						
21.8401	21.8395	21.8390	21.8387	21.8385	21.8385	1.6492	6691.0332
1.9194	1.9130	1.9066	1.9002	1.8938	1.8874	1.8810	1.8746
0.0150	1.6520						
21.8759	21.8753	21.8748	21.8745	21.8744	21.8744	1.6519	6774.6709
1.9194	1.9132	1.9070	1.9008	1.8945	1.8883	1.8821	1.8759
0.0150	1.6546						
21.9107	21.9101	21.9097	21.9094	21.9092	21.9092	1.6545	6858.3091
1.9194	1.9134	1.9073	1.9013	1.8952	1.8891	1.8831	1.8770
0.0150	1.6572						
21.9446	21.9440	21.9436	21.9433	21.9432	21.9432	1.6571	6941.9473
1.9194	1.9135	1.9076	1.9018	1.8959	1.8900	1.8841	1.8782
0.0150	1.6596						
21.9776	21.9770	21.9766	21.9763	21.9762	21.9762	1.6596	7025.5850
1.9194	1.9137	1.9080	1.9022	1.8965	1.8908	1.8850	1.8793
0.0150	1.6621						
22.0096	22.0091	22.0087	22.0084	22.0083	22.0083	1.6620	7109.2227
1.9194	1.9139	1.9083	1.9027	1.8971	1.8915	1.8860	1.8804
0.0150	1.6644						
22.0408	22.0403	22.0399	22.0396	22.0395	22.0395	1.6644	7192.8604
1.9194	1.9140	1.9086	1.9031	1.8977	1.8923	1.8869	1.8814
0.0150	1.6667						
22.0712	22.0707	22.0703	22.0700	22.0699	22.0699	1.6666	7276.4990
1.9194	1.9142	1.9089	1.9036	1.8983	1.8930	1.8877	1.8824
0.0150	1.6689						
22.1008	22.1003	22.0999	22.0996	22.0995	22.0995	1.6689	7360.1367
1.9194	1.9143	1.9091	1.9040	1.8989	1.8937	1.8886	1.8834
0.0151	1.6711						
22.1295	22.1291	22.1287	22.1284	22.1283	22.1283	1.6711	7443.7744
1.9194	1.9144	1.9094	1.9044	1.8994	1.8944	1.8894	1.8844
0.0151	1.6732						
22.1575	22.1571	22.1567	22.1565	22.1564	22.1564	1.6732	7527.4121
1.9194	1.9146	1.9097	1.9048	1.8999	1.8951	1.8902	1.8853
0.0151	1.6753						
22.1848	22.1843	22.1840	22.1838	22.1836	22.1836	1.6752	7611.0508
1.9194	1.9147	1.9099	1.9052	1.9004	1.8957	1.8910	1.8862
0.0151	1.6773						
22.2113	22.2109	22.2106	22.2103	22.2102	22.2102	1.6772	7694.6885
1.9194	1.9148	1.9102	1.9056	1.9010	1.8963	1.8917	1.8871
0.0151	1.6792						
22.2372	22.2367	22.2364	22.2362	22.2361	22.2361	1.6792	7778.3262
1.9194	1.9149	1.9104	1.9059	1.9014	1.8969	1.8924	1.8880
0.0151	1.6811						
22.2623	22.2619	22.2616	22.2614	22.2613	22.2613	1.6811	7861.9639
1.9194	1.9151	1.9107	1.9063	1.9019	1.8975	1.8932	1.8888
0.0151	1.6830						
22.2868	22.2864	22.2861	22.2859	22.2858	22.2858	1.6829	7945.6021
1.9194	1.9152	1.9109	1.9066	1.9024	1.8981	1.8938	1.8896
0.0151	1.6848						
22.3107	22.3103	22.3100	22.3098	22.3097	22.3097	1.6847	8029.2402
1.9194	1.9153	1.9111	1.9070	1.9028	1.8987	1.8945	1.8904
0.0151	1.6866						
22.3339	22.3335	22.3332	22.3330	22.3329	22.3329	1.6865	8112.8779
1.9194	1.9154	1.9114	1.9073	1.9033	1.8992	1.8952	1.8911
0.0151	1.6883						

22.3565	22.3561	22.3558	22.3556	22.3555	22.3555	1.6882	8196.5156
1.9194	1.9155	1.9116	1.9076	1.9037	1.8997	1.8958	1.8919
0.0151	1.6899						
22.3785	22.3782	22.3779	22.3777	22.3776	22.3776	1.6899	8280.1543
1.9194	1.9156	1.9118	1.9079	1.9041	1.9003	1.8964	1.8926
0.0151	1.6915						
22.4000	22.3996	22.3994	22.3992	22.3991	22.3991	1.6915	8363.7920
1.9194	1.9157	1.9120	1.9082	1.9045	1.9008	1.8970	1.8933
0.0151	1.6931						
22.4209	22.4205	22.4203	22.4201	22.4200	22.4200	1.6931	8447.4297
1.9194	1.9158	1.9122	1.9085	1.9049	1.9012	1.8976	1.8940
0.0151	1.6947						
22.4412	22.4409	22.4406	22.4405	22.4404	22.4404	1.6946	8531.0674
1.9194	1.9159	1.9123	1.9088	1.9053	1.9017	1.8982	1.8946
0.0151	1.6962						
22.4611	22.4607	22.4605	22.4603	22.4602	22.4602	1.6961	8614.7051
1.9194	1.9160	1.9125	1.9091	1.9056	1.9022	1.8987	1.8953
0.0151	1.6976						
22.4804	22.4800	22.4798	22.4796	22.4795	22.4795	1.6976	8698.3438
1.9194	1.9161	1.9127	1.9093	1.9060	1.9026	1.8993	1.8959
0.0152	1.6990						
22.4992	22.4989	22.4986	22.4985	22.4984	22.4984	1.6990	8781.9814
1.9194	1.9162	1.9129	1.9096	1.9063	1.9030	1.8998	1.8965
0.0152	1.7004						
22.5175	22.5172	22.5170	22.5168	22.5167	22.5167	1.7004	8865.6191
1.9194	1.9163	1.9131	1.9099	1.9067	1.9035	1.9003	1.8971
0.0152	1.7018						
22.5354	22.5351	22.5348	22.5347	22.5346	22.5346	1.7017	8949.2568
1.9194	1.9163	1.9132	1.9101	1.9070	1.9039	1.9008	1.8977
0.0152	1.7031						
22.5528	22.5525	22.5522	22.5521	22.5520	22.5520	1.7030	9032.8945
1.9194	1.9164	1.9134	1.9103	1.9073	1.9043	1.9012	1.8982
0.0152	1.7044						
22.5697	22.5694	22.5692	22.5691	22.5690	22.5690	1.7043	9116.5332
1.9194	1.9165	1.9135	1.9106	1.9076	1.9047	1.9017	1.8988
0.0152	1.7056						
22.5862	22.5859	22.5857	22.5856	22.5855	22.5855	1.7056	9200.1709

```
 All data are checked successfully !!!
 Re-check all data entered
 ------------------------------------------------------------------
Temperature of storage environment incelsius =25.00
Relative humidity of storage environment in % =90.00
Absolute humidity of storage environment ingH20/gAir =.0183
Diffusion coefficient of packaging materialin 10^-7 cm^2/sec =0.020
Henry constant of packaging material in(gH2O/cm^3 PKG)/(gH2O/cm^3 Air) =   125.12
 000
Thickness of packaging material in cm =   0.01140
Surface area of packaging material in cm^2 =   3.78000
Volume of packaging material in cm^3 =   0.80000
Diffusion coefficient of product in 10^-5cm^2/sec =   0.11790
Initial moisture content in gH2O/100g dryproduct =0.00
Critical moisture content in gH2O/100g dryproduct =2.00
Dry weight of product in g =    0.40770
Chemical reaction rate =   0.0
Chemical reaction order =   0.0
Aw/M=-.1790E+01 Aw^2 + 0.1922E+01 Aw+ 0.6400E-01
Radius of product in cm =    0.50000
Thickness of product (Only Plate shape) incm =   0.39200
 -----------------------------------------------------------------------
            Hit any key to continue.....
 ----------------------------------------------------------------------
 INITIAL CONCENTRATION
 ----------------------------------------------------------------------
Concentration of outside environment (CE) =  0.01938  g/L
Concentration of outside surface of PKG(CLE) =  2.42433  g/L
Concentration of inside surface of PKG(CLH) =  0.00002  g/L
Concentration of headspace (CH) =  0.00000  g/L
Concentration of outside surface of product(CRH) =  0.00132  g/L
 ---------------------------------------------------------------------
 DIMENSSIONLESS CONSTANT
 ---------------------------------------------------------------------
Q=0.1260E-02
G=0.1700E-02
A1=0.1815E-04
B1=0.2127E-03
S=0.2215E+01
X=0.9000E+03
 =    7
 ---------------------------------------------------------------------
           Hit any key to continue ......
 ---------------------------------------------------------------------
    Enter the number of time to calculateconcentrations at once.

         <NOTICE !!!  It must be over 200 and be times of 200>
 -----------------------------------------------------------------------
```

CONCENTRATON PROFILE IN PRODUCT
(Plate Shape)
Each step is 137000. steps (84.3120hrs)
<# of the divided shell of product is 5

CLE	CL1	CL2	CL3	CL4	CLH	CH	Meq
CRH	CR1	CR2	CR3	CR4	CRC	GAIN	TIME(hrs)
2.4243	2.0819	1.7395	1.3971	1.0549	0.7127	0.3707	0.0290
0.0002	0.1273						
1.6856	1.6564	1.6346	1.6200	1.6127	1.6127	0.1234	84.3120
2.4243	2.0894	1.7545	1.4198	1.0852	0.7509	0.4169	0.0833
0.0007	0.2540						
3.3635	3.3351	3.3137	3.2995	3.2924	3.2924	0.2502	168.6240
2.4243	2.1053	1.7863	1.4676	1.1493	0.8316	0.5145	0.1983
0.0016	0.3760						
4.9788	4.9518	4.9316	4.9181	4.9114	4.9114	0.3724	252.9361
2.4243	2.1366	1.8492	1.5622	1.2758	0.9904	0.7060	0.4230
0.0034	0.4882						
6.4646	6.4405	6.4224	6.4104	6.4044	6.4044	0.4850	337.2481
2.4243	2.1758	1.9276	1.6797	1.4326	1.1862	0.9410	0.6970
0.0056	0.5861						
7.7616	7.7408	7.7252	7.7149	7.7097	7.7097	0.5834	421.5601
2.4243	2.2092	1.9943	1.7797	1.5656	1.3521	1.1396	0.9280
0.0074	0.6706						
8.8809	8.8629	8.8493	8.8403	8.8358	8.8358	0.6683	505.8722
2.4243	2.2350	2.0457	1.8567	1.6681	1.4800	1.2926	1.1060
0.0088	0.7446						
9.8605	9.8446	9.8327	9.8248	9.8208	9.8208	0.7425	590.1841
2.4243	2.2549	2.0856	1.9165	1.7477	1.5793	1.4114	1.2441
0.0099	0.8105						
10.7325	10.7183	10.7076	10.7005	10.6969	10.6969	0.8086	674.4962
2.4243	2.2708	2.1173	1.9640	1.8109	1.6582	1.5059	1.3540
0.0108	0.8699						
11.5196	11.5067	11.4970	11.4905	11.4873	11.4873	0.8682	758.8082
2.4243	2.2837	2.1431	2.0027	1.8625	1.7225	1.5829	1.4437
0.0115	0.9242						
12.2381	12.2263	12.2174	12.2114	12.2085	12.2085	0.9226	843.1202
2.4243	2.2945	2.1646	2.0349	1.9054	1.7761	1.6471	1.5184
0.0121	0.9741						
12.8999	12.8890	12.8808	12.8753	12.8725	12.8725	0.9727	927.4323
2.4243	2.3036	2.1829	2.0623	1.9418	1.8215	1.7015	1.5818
0.0126	1.0205						
13.5140	13.5038	13.4961	13.4910	13.4885	13.4885	1.0192	1011.7443
2.4243	2.3114	2.1985	2.0858	1.9731	1.8606	1.7483	1.6363
0.0131	1.0638						
14.0871	14.0776	14.0704	14.0657	14.0633	14.0633	1.0625	1096.0563
2.4243	2.3182	2.2122	2.1062	2.0004	1.8947	1.7891	1.6838
0.0135	1.1044						
14.6248	14.6159	14.6091	14.6046	14.6024	14.6024	1.1032	1180.3683
2.4243	2.3243	2.2242	2.1243	2.0244	1.9246	1.8251	1.7257
0.0138	1.1427						
15.1314	15.1229	15.1165	15.1123	15.1102	15.1102	1.1415	1264.6804
2.4243	2.3296	2.2349	2.1403	2.0457	1.9513	1.8570	1.7629
0.0141	1.1788						
15.6103	15.6023	15.5963	15.5923	15.5903	15.5903	1.1778	1348.9923
2.4243	2.3344	2.2445	2.1546	2.0649	1.9752	1.8857	1.7963
0.0144	1.2131						
16.0646	16.0570	16.0513	16.0475	16.0456	16.0456	1.2121	1433.3044
2.4243	2.3387	2.2531	2.1676	2.0821	1.9968	1.9115	1.8264

0.0146	1.2458						
16.4967	16.4894	16.4840	16.4804	16.4786	16.4786	1.2448	1517.6163
2.4243	2.3426	2.2610	2.1794	2.0978	2.0163	1.9350	1.8537
0.0148	1.2769						
16.9087	16.9018	16.8966	16.8931	16.8914	16.8914	1.2759	1601.9285
2.4243	2.3462	2.2681	2.1901	2.1121	2.0342	1.9564	1.8787
0.0150	1.3066						
17.3024	17.2957	17.2908	17.2875	17.2858	17.2858	1.3057	1686.2404
2.4243	2.3495	2.2747	2.1999	2.1252	2.0506	1.9760	1.9016
0.0152	1.3351						
17.6793	17.6729	17.6682	17.6650	17.6634	17.6634	1.3342	1770.5525
2.4243	2.3525	2.2808	2.2090	2.1373	2.0657	1.9941	1.9227
0.0154	1.3624						
18.0407	18.0346	18.0301	18.0270	18.0255	18.0255	1.3615	1854.8646
2.4243	2.3553	2.2863	2.2174	2.1485	2.0796	2.0109	1.9422
0.0155	1.3886						
18.3880	18.3821	18.3777	18.3748	18.3733	18.3733	1.3878	1939.1765
2.4243	2.3579	2.2915	2.2252	2.1588	2.0926	2.0264	1.9603
0.0157	1.4138						
18.7220	18.7164	18.7121	18.7093	18.7079	18.7079	1.4131	2023.4886
2.4243	2.3603	2.2964	2.2324	2.1685	2.1046	2.0408	1.9771
0.0158	1.4381						
19.0437	19.0383	19.0342	19.0315	19.0302	19.0302	1.4374	2107.8005
2.4243	2.3626	2.3009	2.2392	2.1775	2.1159	2.0543	1.9929
0.0159	1.4615						
19.3540	19.3488	19.3448	19.3422	19.3409	19.3409	1.4608	2192.1125
2.4243	2.3647	2.3051	2.2455	2.1859	2.1264	2.0670	2.0076
0.0160	1.4841						
19.6536	19.6485	19.6447	19.6422	19.6409	19.6409	1.4835	2276.4248
2.4243	2.3667	2.3091	2.2514	2.1939	2.1363	2.0789	2.0214
0.0162	1.5060						
19.9431	19.9382	19.9345	19.9321	19.9309	19.9309	1.5054	2360.7366
2.4243	2.3686	2.3128	2.2570	2.2013	2.1456	2.0900	2.0345
0.0163	1.5272						
20.2232	20.2184	20.2149	20.2125	20.2113	20.2113	1.5265	2445.0486
2.4243	2.3703	2.3163	2.2623	2.2083	2.1544	2.1006	2.0467
0.0164	1.5476						
20.4943	20.4897	20.4863	20.4840	20.4829	20.4829	1.5470	2529.3608
2.4243	2.3720	2.3196	2.2673	2.2150	2.1627	2.1105	2.0583
0.0165	1.5675						
20.7571	20.7527	20.7493	20.7471	20.7460	20.7460	1.5669	2613.6729
2.4243	2.3735	2.3228	2.2720	2.2213	2.1706	2.1199	2.0693
0.0165	1.5867						
21.0119	21.0076	21.0044	21.0022	21.0011	21.0011	1.5862	2697.9846
2.4243	2.3750	2.3257	2.2765	2.2272	2.1780	2.1288	2.0797
0.0166	1.6054						
21.2592	21.2550	21.2519	21.2498	21.2487	21.2487	1.6048	2782.2966
2.4243	2.3765	2.3286	2.2807	2.2329	2.1851	2.1373	2.0896
0.0167	1.6235						
21.4993	21.4953	21.4922	21.4902	21.4892	21.4892	1.6230	2866.6089
2.4243	2.3778	2.3313	2.2847	2.2383	2.1918	2.1454	2.0990
0.0168	1.6412						
21.7327	21.7287	21.7258	21.7238	21.7228	21.7228	1.6406	2950.9209
2.4243	2.3791	2.3338	2.2886	2.2434	2.1982	2.1530	2.1079
0.0168	1.6583						
21.9596	21.9557	21.9528	21.9509	21.9499	21.9499	1.6578	3035.2327
2.4243	2.3803	2.3363	2.2923	2.2483	2.2043	2.1604	2.1165
0.0169	1.6750						
22.1803	22.1765	22.1737	22.1718	22.1709	22.1709	1.6745	3119.5449
2.4243	2.3815	2.3386	2.2958	2.2529	2.2101	2.1674	2.1246

0.0170	1.6912						
22.3951	22.3914	22.3887	22.3869	22.3860	22.3860	1.6907	3203.8569
2.4243	2.3826	2.3408	2.2991	2.2574	2.2157	2.1740	2.1324
0.0170	1.7070						
22.6043	22.6008	22.5981	22.5963	22.5954	22.5954	1.7065	3288.1689
2.4243	2.3836	2.3430	2.3023	2.2616	2.2210	2.1804	2.1399
0.0171	1.7224						
22.8081	22.8047	22.8021	22.8003	22.7995	22.7995	1.7219	3372.4807
2.4243	2.3847	2.3450	2.3054	2.2657	2.2261	2.1866	2.1470
0.0172	1.7374						
23.0068	23.0034	23.0009	22.9992	22.9984	22.9984	1.7369	3456.7930
2.4243	2.3857	2.3470	2.3083	2.2697	2.2310	2.1924	2.1539
0.0172	1.7520						
23.2006	23.1973	23.1948	23.1932	23.1923	23.1923	1.7516	3541.1050
2.4243	2.3866	2.3489	2.3111	2.2734	2.2357	2.1981	2.1604
0.0173	1.7663						
23.3896	23.3864	23.3839	23.3823	23.3815	23.3815	1.7658	3625.4170
2.4243	2.3875	2.3507	2.3138	2.2770	2.2402	2.2035	2.1667
0.0173	1.7802						
23.5740	23.5709	23.5685	23.5670	23.5662	23.5662	1.7798	3709.7292
2.4243	2.3884	2.3524	2.3164	2.2805	2.2446	2.2087	2.1728
0.0174	1.7938						
23.7541	23.7510	23.7488	23.7472	23.7465	23.7465	1.7934	3794.0410
2.4243	2.3892	2.3541	2.3190	2.2838	2.2488	2.2137	2.1787
0.0174	1.8071						
23.9300	23.9270	23.9248	23.9233	23.9225	23.9225	1.8067	3878.3530
2.4243	2.3900	2.3557	2.3214	2.2871	2.2528	2.2185	2.1843
0.0175	1.8201						
24.1018	24.0989	24.0967	24.0952	24.0945	24.0945	1.8197	3962.6653
2.4243	2.3908	2.3572	2.3237	2.2902	2.2567	2.2232	2.1897
0.0175	1.8327						
24.2697	24.2669	24.2647	24.2633	24.2626	24.2626	1.8324	4046.9773
2.4243	2.3915	2.3587	2.3259	2.2932	2.2604	2.2277	2.1950
0.0175	1.8451						
24.4339	24.4311	24.4290	24.4276	24.4269	24.4269	1.8448	4131.2891
2.4243	2.3923	2.3602	2.3281	2.2961	2.2640	2.2320	2.2000
0.0176	1.8573						
24.5944	24.5917	24.5896	24.5883	24.5876	24.5876	1.8569	4215.6011
2.4243	2.3930	2.3616	2.3302	2.2988	2.2675	2.2362	2.2049
0.0176	1.8691						
24.7514	24.7488	24.7468	24.7454	24.7447	24.7447	1.8688	4299.9136
2.4243	2.3936	2.3629	2.3322	2.3015	2.2709	2.2402	2.2096
0.0177	1.8807						
24.9051	24.9024	24.9005	24.8992	24.8985	24.8985	1.8804	4384.2251
2.4243	2.3943	2.3642	2.3342	2.3042	2.2741	2.2441	2.2142
0.0177	1.8921						
25.0554	25.0528	25.0509	25.0496	25.0490	25.0490	1.8917	4468.5371
2.4243	2.3949	2.3655	2.3361	2.3067	2.2773	2.2479	2.2186
0.0177	1.9032						
25.2026	25.2001	25.1982	25.1969	25.1963	25.1963	1.9029	4552.8496
2.4243	2.3955	2.3667	2.3379	2.3091	2.2803	2.2516	2.2228
0.0178	1.9141						
25.3467	25.3442	25.3424	25.3412	25.3406	25.3406	1.9137	4637.1616
2.4243	2.3961	2.3679	2.3397	2.3115	2.2833	2.2551	2.2270
0.0178	1.9247						
25.4878	25.4854	25.4836	25.4824	25.4818	25.4818	1.9244	4721.4731
2.4243	2.3967	2.3690	2.3414	2.3138	2.2862	2.2586	2.2310
0.0178	1.9352						
25.6261	25.6237	25.6220	25.6208	25.6202	25.6202	1.9349	4805.7856
2.4243	2.3972	2.3702	2.3431	2.3160	2.2889	2.2619	2.2349

```
 0.0179   1.9454
25.7616  25.7593  25.7575  25.7564  25.7558  25.7558   1.9451  4890.0972
 2.4243   2.3978   2.3712   2.3447   2.3182   2.2916   2.2651     2.2386
 0.0179   1.9554
25.8943  25.8921  25.8904  25.8893  25.8887  25.8887   1.9551  4974.4097
 2.4243   2.3983   2.3723   2.3463   2.3203   2.2943   2.2683     2.2423
 0.0179   1.9652
26.0245  26.0223  26.0206  26.0195  26.0189  26.0189   1.9650  5058.7217
 2.4243   2.3988   2.3733   2.3478   2.3223   2.2968   2.2713     2.2459
 0.0179   1.9749
26.1521  26.1499  26.1483  26.1472  26.1466  26.1466   1.9746  5143.0332
 2.4243   2.3993   2.3743   2.3493   2.3243   2.2993   2.2743     2.2493
 0.0180   1.9843
26.2772  26.2751  26.2735  26.2724  26.2719  26.2719   1.9840  5227.3457
 2.4243   2.3998   2.3752   2.3507   2.3262   2.3017   2.2772     2.2527
 0.0180   1.9936
26.3999  26.3978  26.3962  26.3952  26.3947  26.3947   1.9933  5311.6577
--------------------------------------------------------------------------
              SHELF-LIFE OF THIS PRODUCT IS      5373.44531hrs
------------------------------------------------------------------------
FORTRAN STOP
$
```

```
All data are checked successfully !!!
Re-check all data entered
-----------------------------------------------------------------
Temperature of storage environment incelsius =25.00
Relative humidity of storage environment in % =80.00
Absolute humidity of storage environment ingH2O/gAir =.0163
Diffusion coefficient of packaging materialin 10^-7 cm^2/sec =0.020
Henry constant of packaging material in(gH2O/cm^3 PKG)/(gH2O/cm^3 Air) =   125.12
000
Thickness of packaging material in cm =   0.02300
Surface area of packaging material in cm^2 =   3.78000
Volume of packaging material in cm^3 =   0.80000
Diffusion coefficient of product in 10^-5cm^2/sec =   0.11790
Initial moisture content in gH2O/100g dryproduct =0.00
Critical moisture content in gH2O/100g dryproduct =2.00
Dry weight of product in g =   0.40770
Chemical reaction rate =   0.0
Chemical reaction order =   0.0
Aw/M=-.1790E+01 Aw^2 + 0.1922E+01 Aw+ 0.6400E-01
Radius of product in cm =   0.50000
Thickness of product (Only Plate shape) incm =   0.39200
----------------------------------------------------------------------
           Hit any key to continue.....
----------------------------------------------------------------------
INITIAL CONCENTRATION
----------------------------------------------------------------------
Concentration of outside environment (CE) =  0.01534  g/L
Concentration of outside surface of PKG(CLE) =  1.91945  g/L
Concentration of inside surface of PKG(CLH) =  0.00002  g/L
Concentration of headspace (CH) =  0.00000  g/L
Concentration of outside surface of product(CRH) =  0.00132  g/L
---------------------------------------------------------------------
DIMENSSIONLESS CONSTANT
---------------------------------------------------------------------
Q=0.1420E-02
G=0.1520E-02
A1=0.1822E-04
B1=0.1902E-03
S=0.1981E+01
X=0.9000E+03
 =   14
---------------------------------------------------------------------
          Hit any key to continue ......
---------------------------------------------------------------------
    Enter the number of time to calculateconcentrations at once.

         <NOTICE !!!  It must be over 200 and be times of 200>
----------------------------------------------------------------------
```

(Plate Shape)
Each step is 152000. steps (83.6379hrs)
<# of the divided shell of product is 5

CLE	CL1	CL2	CL3	CL4	CLH	CH	Meq
CRH	CR1	CR2	CR3	CR4	CRC	GAIN	TIME(hrs)
1.9194	1.7828	1.6462	1.5096	1.3730	1.2365	1.0999	0.9634
0.8269	0.6904	0.5540	0.4175	0.2812	0.1449	0.0086	0.0001
0.0504							
0.6676	0.6545	0.6448	0.6382	0.6350	0.6350	0.0487	83.6379
1.9194	1.7837	1.6479	1.5122	1.3764	1.2407	1.1050	0.9693
0.8337	0.6980	0.5625	0.4269	0.2915	0.1560	0.0207	0.0002
0.1071							
1.4189	1.4059	1.3962	1.3897	1.3865	1.3865	0.1054	167.2758
1.9194	1.7848	1.6501	1.5154	1.3807	1.2461	1.1115	0.9769
0.8424	0.7079	0.5735	0.4391	0.3048	0.1705	0.0364	0.0003
0.1634							
2.1642	2.1514	2.1417	2.1353	2.1321	2.1321	0.1617	250.9138
1.9194	1.7862	1.6529	1.5197	1.3864	1.2533	1.1201	0.9870
0.8539	0.7209	0.5880	0.4552	0.3224	0.1898	0.0572	0.0005
0.2191							
2.9017	2.8890	2.8795	2.8731	2.8700	2.8700	0.2174	334.5517
1.9194	1.7881	1.6568	1.5255	1.3942	1.2630	1.1318	1.0007
0.8697	0.7388	0.6079	0.4772	0.3466	0.2161	0.0857	0.0007
0.2740							
3.6285	3.6160	3.6067	3.6004	3.5973	3.5973	0.2724	418.1896
1.9194	1.7908	1.6622	1.5336	1.4051	1.2766	1.1482	1.0199
0.8917	0.7636	0.6357	0.5079	0.3803	0.2528	0.1256	0.0010
0.3278							
4.3404	4.3282	4.3191	4.3130	4.3100	4.3100	0.3262	501.8275
1.9194	1.7946	1.6698	1.5451	1.4204	1.2958	1.1713	1.0469
0.9227	0.7986	0.6748	0.5511	0.4277	0.3045	0.1816	0.0015
0.3799							
5.0314	5.0196	5.0108	5.0049	5.0020	5.0020	0.3784	585.4654
1.9194	1.7998	1.6803	1.5607	1.4413	1.3220	1.2028	1.0838
0.9649	0.8463	0.7280	0.6099	0.4921	0.3747	0.2576	0.0021
0.4300							
5.6936	5.6824	5.6740	5.6684	5.6656	5.6656	0.4285	669.1033
1.9194	1.8064	1.6934	1.5805	1.4677	1.3549	1.2424	1.1301
1.0180	0.9061	0.7946	0.6834	0.5725	0.4621	0.3521	0.0028
0.4772							
6.3194	6.3089	6.3010	6.2957	6.2931	6.2931	0.4758	752.7413
1.9194	1.8138	1.7082	1.6027	1.4972	1.3919	1.2868	1.1819
1.0773	0.9729	0.8688	0.7651	0.6617	0.5588	0.4564	0.0036
0.5214							
6.9042	6.8944	6.8871	6.8822	6.8798	6.8798	0.5201	836.3792
1.9194	1.8213	1.7231	1.6250	1.5271	1.4292	1.3316	1.2341
1.1369	1.0399	0.9432	0.8469	0.7510	0.6554	0.5603	0.0045
0.5624							
7.4476	7.4386	7.4317	7.4272	7.4249	7.4249	0.5612	920.0171
1.9194	1.8283	1.7372	1.6461	1.5551	1.4643	1.3736	1.2831
1.1928	1.1027	1.0130	0.9235	0.8344	0.7456	0.6573	0.0053
0.6005							
7.9521	7.9437	7.9374	7.9331	7.9310	7.9310	0.5994	1003.6550
1.9194	1.8346	1.7499	1.6652	1.5805	1.4960	1.4116	1.3274
1.2434	1.1596	1.0760	0.9928	0.9098	0.8271	0.7448	0.0060
0.6359							
8.4214	8.4135	8.4076	8.4037	8.4017	8.4017	0.6349	1087.2930
1.9194	1.8403	1.7612	1.6822	1.6032	1.5243	1.4455	1.3669

1.2885	1.2102	1.1322	1.0545	0.9769	0.8997	0.8228	0.0066
0.6690							
8.8593	8.8519	8.8464	8.8427	8.8409	8.8409	0.6680	1170.9308
1.9194	1.8454	1.7713	1.6972	1.6233	1.5494	1.4756	1.4020
1.3285	1.2552	1.1821	1.1092	1.0366	0.9642	0.8920	0.0071
0.7000							
9.2693	9.2624	9.2572	9.2538	9.2521	9.2521	0.6991	1254.5687
1.9194	1.8498	1.7802	1.7107	1.6412	1.5717	1.5024	1.4332
1.3641	1.2952	1.2264	1.1579	1.0895	1.0214	0.9536	0.0076
0.7291							
9.6545	9.6481	9.6432	9.6399	9.6383	9.6383	0.7282	1338.2067
1.9194	1.8538	1.7882	1.7226	1.6571	1.5916	1.5263	1.4610
1.3958	1.3308	1.2660	1.2013	1.1368	1.0725	1.0085	0.0081
0.7565							
10.0177	10.0116	10.0070	10.0040	10.0024	10.0024	0.7557	1421.8446
1.9194	1.8574	1.7953	1.7333	1.6714	1.6095	1.5476	1.4859
1.4243	1.3628	1.3014	1.2402	1.1792	1.1184	1.0577	0.0085
0.7824							
10.3612	10.3554	10.3510	10.3481	10.3467	10.3467	0.7817	1505.4825
1.9194	1.8606	1.8018	1.7430	1.6842	1.6255	1.5669	1.5083
1.4499	1.3916	1.3334	1.2753	1.2174	1.1596	1.1021	0.0088
0.8070							
10.6868	10.6813	10.6771	10.6744	10.6730	10.6730	0.8063	1589.1204
1.9194	1.8635	1.8076	1.7517	1.6959	1.6401	1.5843	1.5287
1.4731	1.4176	1.3623	1.3070	1.2520	1.1970	1.1423	0.0091
0.8304							
10.9963	10.9910	10.9871	10.9845	10.9832	10.9832	0.8297	1672.7583
1.9194	1.8662	1.8129	1.7597	1.7064	1.6533	1.6002	1.5471
1.4942	1.4413	1.3886	1.3359	1.2834	1.2310	1.1788	0.0094
0.8527							
11.2911	11.2861	11.2824	11.2799	11.2786	11.2786	0.8520	1756.3962
1.9194	1.8686	1.8177	1.7669	1.7161	1.6654	1.6146	1.5640
1.5134	1.4630	1.4126	1.3623	1.3122	1.2621	1.2122	0.0097
0.8739							
11.5726	11.5678	11.5642	11.5618	11.5606	11.5606	0.8733	1840.0342
1.9194	1.8708	1.8222	1.7736	1.7250	1.6764	1.6279	1.5795
1.5311	1.4828	1.4346	1.3865	1.3385	1.2907	1.2429	0.0099
0.8942							
11.8417	11.8372	11.8337	11.8315	11.8303	11.8303	0.8936	1923.6721
1.9194	1.8728	1.8263	1.7797	1.7331	1.6866	1.6402	1.5938
1.5474	1.5011	1.4549	1.4088	1.3628	1.3169	1.2712	0.0102
0.9137							
12.0996	12.0952	12.0919	12.0898	12.0887	12.0887	0.9131	2007.3101
1.9194	1.8747	1.8300	1.7853	1.7407	1.6961	1.6515	1.6069
1.5625	1.5181	1.4737	1.4295	1.3853	1.3413	1.2973	0.0104
0.9324							
12.3470	12.3428	12.3397	12.3376	12.3365	12.3365	0.9318	2090.9480
1.9194	1.8765	1.8335	1.7906	1.7477	1.7048	1.6620	1.6192
1.5764	1.5337	1.4911	1.4486	1.4062	1.3638	1.3216	0.0106
0.9503							
12.5848	12.5807	12.5777	12.5757	12.5747	12.5747	0.9498	2174.5859
1.9194	1.8781	1.8368	1.7955	1.7542	1.7129	1.6717	1.6305
1.5894	1.5483	1.5073	1.4664	1.4256	1.3848	1.3441	0.0107
0.9676							
12.8135	12.8096	12.8067	12.8047	12.8037	12.8037	0.9671	2258.2236
1.9194	1.8796	1.8398	1.8000	1.7603	1.7205	1.6808	1.6411
1.6015	1.5620	1.5224	1.4830	1.4436	1.4044	1.3652	0.0109
0.9842							
13.0338	13.0300	13.0272	13.0253	13.0244	13.0244	0.9838	2341.8616
1.9194	1.8811	1.8427	1.8043	1.7659	1.7276	1.6893	1.6511

1.6129	1.5747	1.5366	1.4985	1.4606	1.4227	1.3849	0.0111
1.0003							
13.2462	13.2426	13.2399	13.2381	13.2372	13.2372	0.9998	2425.4995
1.9194	1.8824	1.8453	1.8083	1.7713	1.7343	1.6973	1.6604
1.6235	1.5866	1.5498	1.5131	1.4764	1.4399	1.4033	0.0112
1.0158							
13.4513	13.4478	13.4452	13.4434	13.4426	13.4426	1.0153	2509.1375
1.9194	1.8836	1.8478	1.8120	1.7763	1.7405	1.7048	1.6691
1.6335	1.5979	1.5623	1.5268	1.4914	1.4560	1.4207	0.0114
1.0307							
13.6494	13.6461	13.6435	13.6418	13.6410	13.6410	1.0303	2592.7754
1.9194	1.8848	1.8502	1.8156	1.7810	1.7464	1.7119	1.6773
1.6429	1.6084	1.5740	1.5397	1.5054	1.4712	1.4371	0.0115
1.0452							
13.8411	13.8378	13.8353	13.8337	13.8329	13.8329	1.0448	2676.4133
1.9194	1.8859	1.8524	1.8189	1.7854	1.7520	1.7185	1.6851
1.6517	1.6184	1.5851	1.5519	1.5187	1.4856	1.4525	0.0116
1.0592							
14.0265	14.0234	14.0210	14.0194	14.0186	14.0186	1.0588	2760.0510
1.9194	1.8870	1.8545	1.8221	1.7896	1.7572	1.7248	1.6925
1.6601	1.6278	1.5956	1.5634	1.5312	1.4991	1.4671	0.0117
1.0728							
14.2062	14.2031	14.2008	14.1993	14.1985	14.1985	1.0724	2843.6892
1.9194	1.8880	1.8565	1.8251	1.7936	1.7622	1.7308	1.6994
1.6681	1.6368	1.6055	1.5743	1.5431	1.5120	1.4809	0.0118
1.0859							
14.3803	14.3774	14.3751	14.3736	14.3729	14.3729	1.0855	2927.3269
1.9194	1.8889	1.8584	1.8279	1.7974	1.7669	1.7364	1.7060
1.6756	1.6452	1.6149	1.5846	1.5544	1.5242	1.4940	0.0119
1.0987							
14.5492	14.5464	14.5442	14.5428	14.5420	14.5420	1.0983	3010.9651
1.9194	1.8898	1.8602	1.8306	1.8010	1.7714	1.7418	1.7123
1.6828	1.6533	1.6238	1.5944	1.5650	1.5357	1.5065	0.0120
1.1111							
14.7132	14.7104	14.7083	14.7069	14.7062	14.7062	1.1107	3094.6028
1.9194	1.8907	1.8619	1.8331	1.8044	1.7756	1.7469	1.7182
1.6896	1.6609	1.6323	1.6038	1.5752	1.5467	1.5183	0.0121
1.1231							
14.8724	14.8697	14.8677	14.8663	14.8656	14.8656	1.1227	3178.2407
1.9194	1.8915	1.8635	1.8356	1.8076	1.7797	1.7518	1.7239
1.6960	1.6682	1.6404	1.6126	1.5849	1.5572	1.5296	0.0122
1.1348							
15.0272	15.0245	15.0226	15.0212	15.0206	15.0206	1.1344	3261.8787
1.9194	1.8923	1.8651	1.8379	1.8107	1.7836	1.7564	1.7293
1.7022	1.6752	1.6481	1.6211	1.5942	1.5673	1.5404	0.0123
1.1461							
15.1777	15.1751	15.1732	15.1719	15.1712	15.1712	1.1458	3345.5166
1.9194	1.8930	1.8666	1.8401	1.8137	1.7873	1.7609	1.7345
1.7081	1.6818	1.6555	1.6292	1.6030	1.5768	1.5507	0.0124
1.1572							
15.3240	15.3215	15.3196	15.3184	15.3178	15.3178	1.1569	3429.1545
1.9194	1.8937	1.8680	1.8422	1.8165	1.7908	1.7651	1.7394
1.7138	1.6881	1.6625	1.6370	1.6114	1.5859	1.5605	0.0125
1.1680							
15.4665	15.4640	15.4622	15.4610	15.4604	15.4604	1.1676	3512.7925
1.9194	1.8944	1.8693	1.8443	1.8192	1.7942	1.7692	1.7442
1.7192	1.6942	1.6693	1.6444	1.6195	1.5947	1.5699	0.0125
1.1784							
15.6052	15.6028	15.6010	15.5998	15.5992	15.5992	1.1781	3596.4302
1.9194	1.8950	1.8706	1.8462	1.8218	1.7974	1.7730	1.7487

1.7243	1.7000	1.6757	1.6515	1.6273	1.6031	1.5789	0.0126
1.1886							
15.7403	15.7380	15.7363	15.7351	15.7345	15.7345	1.1883	3680.0684
1.9194	1.8957	1.8719	1.8481	1.8243	1.8005	1.7768	1.7530
1.7293	1.7056	1.6819	1.6583	1.6347	1.6111	1.5876	0.0127
1.1986							
15.8720	15.8697	15.8680	15.8669	15.8664	15.8664	1.1983	3763.7061
1.9194	1.8962	1.8731	1.8499	1.8267	1.8035	1.7803	1.7572
1.7341	1.7110	1.6879	1.6648	1.6418	1.6188	1.5959	0.0128
1.2083							
16.0004	15.9982	15.9965	15.9954	15.9949	15.9949	1.2080	3847.3442
1.9194	1.8968	1.8742	1.8516	1.8290	1.8064	1.7838	1.7612
1.7386	1.7161	1.6936	1.6711	1.6487	1.6262	1.6038	0.0128
1.2177							
16.1256	16.1234	16.1218	16.1208	16.1202	16.1202	1.2174	3930.9819
1.9194	1.8974	1.8753	1.8532	1.8312	1.8091	1.7871	1.7650
1.7430	1.7211	1.6991	1.6772	1.6552	1.6334	1.6115	0.0129
1.2270							
16.2477	16.2457	16.2441	16.2430	16.2425	16.2425	1.2267	4014.6201
1.9194	1.8979	1.8764	1.8548	1.8333	1.8118	1.7903	1.7688
1.7473	1.7258	1.7044	1.6830	1.6616	1.6402	1.6189	0.0129
1.2360							
16.3670	16.3649	16.3634	16.3624	16.3619	16.3619	1.2357	4098.2578
1.9194	1.8984	1.8774	1.8563	1.8353	1.8143	1.7933	1.7723
1.7513	1.7304	1.7095	1.6886	1.6677	1.6468	1.6260	0.0130
1.2447							
16.4834	16.4814	16.4799	16.4789	16.4784	16.4784	1.2445	4181.8960
1.9194	1.8989	1.8784	1.8578	1.8373	1.8168	1.7963	1.7758
1.7553	1.7348	1.7144	1.6939	1.6735	1.6532	1.6328	0.0131
1.2533							
16.5971	16.5951	16.5937	16.5927	16.5922	16.5922	1.2531	4265.5337
1.9194	1.8994	1.8793	1.8592	1.8392	1.8191	1.7991	1.7791
1.7591	1.7391	1.7191	1.6991	1.6792	1.6593	1.6394	0.0131
1.2617							
16.7081	16.7062	16.7048	16.7039	16.7034	16.7034	1.2615	4349.1719
1.9194	1.8998	1.8802	1.8606	1.8410	1.8214	1.8018	1.7823
1.7627	1.7432	1.7237	1.7042	1.6847	1.6652	1.6458	0.0132
1.2699							
16.8167	16.8148	16.8134	16.8125	16.8120	16.8120	1.2697	4432.8096
1.9194	1.9003	1.8811	1.8619	1.8428	1.8236	1.8045	1.7854
1.7662	1.7471	1.7281	1.7090	1.6900	1.6709	1.6520	0.0132
1.2779							
16.9228	16.9209	16.9196	16.9187	16.9182	16.9182	1.2777	4516.4473
1.9194	1.9007	1.8820	1.8632	1.8445	1.8258	1.8070	1.7883
1.7697	1.7510	1.7323	1.7137	1.6951	1.6765	1.6579	0.0133
1.2858							
17.0265	17.0247	17.0234	17.0225	17.0220	17.0220	1.2855	4600.0854
1.9194	1.9011	1.8828	1.8645	1.8461	1.8278	1.8095	1.7912
1.7729	1.7547	1.7364	1.7182	1.7000	1.6818	1.6636	0.0133
1.2934							
17.1279	17.1262	17.1249	17.1240	17.1236	17.1236	1.2932	4683.7231
1.9194	1.9015	1.8836	1.8657	1.8477	1.8298	1.8119	1.7940
1.7761	1.7583	1.7404	1.7226	1.7048	1.6870	1.6692	0.0133
1.3009							
17.2272	17.2255	17.2242	17.2233	17.2229	17.2229	1.3007	4767.3613
1.9194	1.9019	1.8844	1.8668	1.8493	1.8317	1.8142	1.7967
1.7792	1.7617	1.7443	1.7268	1.7094	1.6920	1.6746	0.0134
1.3082							
17.3243	17.3226	17.3214	17.3205	17.3201	17.3201	1.3080	4850.9990
1.9194	1.9023	1.8851	1.8679	1.8508	1.8336	1.8165	1.7993

1.7822	1.7651	1.7480	1.7309	1.7138	1.6968	1.6798	0.0134
1.3154							
17.4193	17.4177	17.4165	17.4156	17.4152	17.4152	1.3152	4934.6372
1.9194	1.9026	1.8858	1.8690	1.8522	1.8354	1.8186	1.8019
1.7851	1.7683	1.7516	1.7349	1.7182	1.7015	1.6848	0.0135
1.3224							
17.5123	17.5107	17.5095	17.5087	17.5083	17.5083	1.3222	5018.2749
1.9194	1.9030	1.8865	1.8701	1.8536	1.8372	1.8207	1.8043
1.7879	1.7715	1.7551	1.7387	1.7224	1.7060	1.6897	0.0135
1.3293							
17.6034	17.6019	17.6007	17.5999	17.5995	17.5995	1.3291	5101.9126
1.9194	1.9033	1.8872	1.8711	1.8550	1.8389	1.8228	1.8067
1.7906	1.7746	1.7585	1.7425	1.7264	1.7104	1.6945	0.0135
1.3361							
17.6926	17.6911	17.6899	17.6892	17.6888	17.6888	1.3359	5185.5508
1.9194	1.9037	1.8879	1.8721	1.8563	1.8405	1.8248	1.8090
1.7933	1.7775	1.7618	1.7461	1.7304	1.7147	1.6991	0.0136
1.3427							
17.7800	17.7785	17.7774	17.7766	17.7762	17.7762	1.3425	5269.1890
1.9194	1.9040	1.8885	1.8730	1.8576	1.8421	1.8267	1.8112
1.7958	1.7804	1.7650	1.7496	1.7342	1.7189	1.7035	0.0136
1.3491							
17.8656	17.8641	17.8630	17.8623	17.8619	17.8619	1.3489	5352.8267
1.9194	1.9043	1.8891	1.8740	1.8588	1.8437	1.8285	1.8134
1.7983	1.7832	1.7681	1.7530	1.7380	1.7229	1.7079	0.0136
1.3555							
17.9495	17.9480	17.9470	17.9462	17.9459	17.9459	1.3553	5436.4644
1.9194	1.9046	1.8897	1.8749	1.8600	1.8452	1.8304	1.8155
1.8007	1.7859	1.7711	1.7563	1.7416	1.7268	1.7121	0.0137
1.3617							
18.0317	18.0303	18.0292	18.0285	18.0282	18.0282	1.3615	5520.1021
1.9194	1.9049	1.8903	1.8758	1.8612	1.8467	1.8321	1.8176
1.8031	1.7885	1.7740	1.7596	1.7451	1.7306	1.7162	0.0137
1.3678							
18.1123	18.1109	18.1099	18.1092	18.1088	18.1088	1.3676	5603.7407
1.9194	1.9052	1.8909	1.8766	1.8624	1.8481	1.8338	1.8196
1.8053	1.7911	1.7769	1.7627	1.7485	1.7343	1.7202	0.0137
1.3737							
18.1913	18.1899	18.1889	18.1882	18.1879	18.1879	1.3735	5687.3784
1.9194	1.9054	1.8915	1.8775	1.8635	1.8495	1.8355	1.8215
1.8076	1.7936	1.7797	1.7657	1.7518	1.7379	1.7240	0.0138
1.3796							
18.2687	18.2674	18.2664	18.2658	18.2654	18.2654	1.3794	5771.0161
1.9194	1.9057	1.8920	1.8783	1.8645	1.8508	1.8371	1.8234
1.8097	1.7960	1.7824	1.7687	1.7550	1.7414	1.7278	0.0138
1.3853							
18.3447	18.3434	18.3424	18.3418	18.3415	18.3415	1.3851	5854.6538
1.9194	1.9060	1.8925	1.8791	1.8656	1.8521	1.8387	1.8252
1.8118	1.7984	1.7850	1.7716	1.7582	1.7448	1.7315	0.0138
1.3909							
18.4192	18.4180	18.4170	18.4164	18.4160	18.4160	1.3908	5938.2920
1.9194	1.9062	1.8930	1.8798	1.8666	1.8534	1.8402	1.8270
1.8139	1.8007	1.7875	1.7744	1.7612	1.7481	1.7350	0.0139
1.3965							
18.4923	18.4911	18.4902	18.4895	18.4892	18.4892	1.3963	6021.9302
1.9194	1.9065	1.8935	1.8806	1.8676	1.8547	1.8417	1.8288
1.8158	1.8029	1.7900	1.7771	1.7642	1.7513	1.7385	0.0139
1.4019							
18.5641	18.5628	18.5619	18.5613	18.5610	18.5610	1.4017	6105.5679
1.9194	1.9067	1.8940	1.8813	1.8686	1.8559	1.8432	1.8305

1.8178	1.8051	1.7924	1.7798	1.7671	1.7545	1.7419	0.0139
1.4072							
18.6345	18.6333	18.6323	18.6317	18.6314	18.6314	1.4070	6189.2056
1.9194	1.9070	1.8945	1.8820	1.8695	1.8571	1.8446	1.8321
1.8197	1.8072	1.7948	1.7824	1.7700	1.7576	1.7452	0.0139
1.4124							
18.7035	18.7024	18.7015	18.7009	18.7006	18.7006	1.4122	6272.8438
1.9194	1.9072	1.8949	1.8827	1.8704	1.8582	1.8460	1.8337
1.8215	1.8093	1.7971	1.7849	1.7727	1.7605	1.7484	0.0140
1.4175							
18.7713	18.7702	18.7693	18.7687	18.7684	18.7684	1.4174	6356.4814
1.9194	1.9074	1.8954	1.8834	1.8713	1.8593	1.8473	1.8353
1.8233	1.8113	1.7993	1.7874	1.7754	1.7634	1.7515	0.0140
1.4226							
18.8379	18.8368	18.8359	18.8353	18.8351	18.8351	1.4224	6440.1196
1.9194	1.9076	1.8958	1.8840	1.8722	1.8604	1.8486	1.8368
1.8251	1.8133	1.8015	1.7898	1.7780	1.7663	1.7546	0.0140
1.4275							
18.9033	18.9021	18.9013	18.9007	18.9005	18.9005	1.4273	6523.7573
1.9194	1.9079	1.8963	1.8847	1.8731	1.8615	1.8499	1.8383
1.8268	1.8152	1.8036	1.7921	1.7806	1.7690	1.7575	0.0140
1.4323							
18.9674	18.9663	18.9655	18.9650	18.9647	18.9647	1.4322	6607.3955
1.9194	1.9081	1.8967	1.8853	1.8739	1.8625	1.8512	1.8398
1.8284	1.8171	1.8057	1.7944	1.7831	1.7717	1.7604	0.0141
1.4371							
19.0304	19.0294	19.0286	19.0280	19.0277	19.0277	1.4369	6691.0332
1.9194	1.9083	1.8971	1.8859	1.8747	1.8635	1.8524	1.8412
1.8300	1.8189	1.8078	1.7966	1.7855	1.7744	1.7633	0.0141
1.4418							
19.0923	19.0913	19.0905	19.0899	19.0897	19.0897	1.4416	6774.6709
1.9194	1.9085	1.8975	1.8865	1.8755	1.8645	1.8536	1.8426
1.8316	1.8207	1.8097	1.7988	1.7879	1.7770	1.7660	0.0141
1.4464							
19.1531	19.1521	19.1513	19.1508	19.1505	19.1505	1.4462	6858.3091
1.9194	1.9087	1.8979	1.8871	1.8763	1.8655	1.8547	1.8439
1.8332	1.8224	1.8117	1.8009	1.7902	1.7795	1.7688	0.0141
1.4509							
19.2129	19.2118	19.2111	19.2105	19.2103	19.2103	1.4507	6941.9473
1.9194	1.9088	1.8982	1.8876	1.8770	1.8664	1.8559	1.8453
1.8347	1.8241	1.8136	1.8030	1.7925	1.7819	1.7714	0.0142
1.4553							
19.2715	19.2705	19.2698	19.2693	19.2690	19.2690	1.4552	7025.5850
1.9194	1.9090	1.8986	1.8882	1.8778	1.8674	1.8570	1.8466
1.8362	1.8258	1.8154	1.8050	1.7947	1.7843	1.7740	0.0142
1.4596							
19.3292	19.3282	19.3275	19.3270	19.3267	19.3267	1.4595	7109.2227
1.9194	1.9092	1.8990	1.8887	1.8785	1.8683	1.8580	1.8478
1.8376	1.8274	1.8172	1.8070	1.7968	1.7867	1.7765	0.0142
1.4639							
19.3858	19.3849	19.3841	19.3836	19.3834	19.3834	1.4638	7192.8604
1.9194	1.9094	1.8993	1.8893	1.8792	1.8692	1.8591	1.8491
1.8390	1.8290	1.8190	1.8089	1.7989	1.7889	1.7789	0.0142
1.4681							
19.4415	19.4406	19.4398	19.4394	19.4391	19.4391	1.4680	7276.4990
1.9194	1.9096	1.8997	1.8898	1.8799	1.8700	1.8601	1.8503
1.8404	1.8305	1.8207	1.8108	1.8010	1.7912	1.7814	0.0142
1.4723							
19.4962	19.4953	19.4946	19.4941	19.4939	19.4939	1.4721	7360.1367
1.9194	1.9097	1.9000	1.8903	1.8806	1.8709	1.8612	1.8514

1.8417	1.8321	1.8224	1.8127	1.8030	1.7934	1.7837	0.0143
1.4763							
19.5500	19.5491	19.5484	19.5479	19.5477	19.5477	1.4762	7443.7744
1.9194	1.9099	1.9003	1.8908	1.8812	1.8717	1.8621	1.8526
1.8431	1.8335	1.8240	1.8145	1.8050	1.7955	1.7860	0.0143
1.4803							
19.6029	19.6020	19.6013	19.6009	19.6006	19.6006	1.4802	7527.4121
1.9194	1.9101	1.9007	1.8913	1.8819	1.8725	1.8631	1.8537
1.8444	1.8350	1.8256	1.8163	1.8069	1.7976	1.7883	0.0143
1.4842							
19.6549	19.6540	19.6533	19.6529	19.6527	19.6527	1.4841	7611.0508
1.9194	1.9102	1.9010	1.8917	1.8825	1.8733	1.8641	1.8548
1.8456	1.8364	1.8272	1.8180	1.8088	1.7996	1.7905	0.0143
1.4881							
19.7060	19.7051	19.7045	19.7040	19.7038	19.7038	1.4880	7694.6885
1.9194	1.9104	1.9013	1.8922	1.8831	1.8740	1.8650	1.8559
1.8468	1.8378	1.8287	1.8197	1.8107	1.8016	1.7926	0.0143
1.4919							
19.7563	19.7554	19.7548	19.7543	19.7541	19.7541	1.4918	7778.3262
1.9194	1.9105	1.9016	1.8927	1.8837	1.8748	1.8659	1.8570
1.8481	1.8391	1.8302	1.8214	1.8125	1.8036	1.7947	0.0143
1.4956							
19.8057	19.8048	19.8042	19.8038	19.8036	19.8036	1.4955	7861.9639
1.9194	1.9107	1.9019	1.8931	1.8843	1.8755	1.8668	1.8580
1.8492	1.8405	1.8317	1.8230	1.8142	1.8055	1.7968	0.0144
1.4993							
19.8543	19.8535	19.8528	19.8524	19.8522	19.8522	1.4992	7945.6021
1.9194	1.9108	1.9022	1.8935	1.8849	1.8763	1.8676	1.8590
1.8504	1.8418	1.8332	1.8246	1.8160	1.8074	1.7988	0.0144
1.5029							
19.9021	19.9013	19.9007	19.9002	19.9000	19.9000	1.5028	8029.2402
1.9194	1.9110	1.9025	1.8940	1.8855	1.8770	1.8685	1.8600
1.8515	1.8430	1.8346	1.8261	1.8177	1.8092	1.8008	0.0144
1.5065							
19.9491	19.9483	19.9477	19.9473	19.9471	19.9471	1.5064	8112.8779
1.9194	1.9111	1.9027	1.8944	1.8860	1.8777	1.8693	1.8610
1.8526	1.8443	1.8360	1.8276	1.8193	1.8110	1.8027	0.0144
1.5100							
19.9954	19.9946	19.9940	19.9936	19.9934	19.9934	1.5099	8196.5156
1.9194	1.9112	1.9030	1.8948	1.8866	1.8783	1.8701	1.8619
1.8537	1.8455	1.8373	1.8291	1.8210	1.8128	1.8046	0.0144
1.5134							
20.0409	20.0401	20.0395	20.0391	20.0389	20.0389	1.5133	8280.1543
1.9194	1.9114	1.9033	1.8952	1.8871	1.8790	1.8709	1.8629
1.8548	1.8467	1.8386	1.8306	1.8225	1.8145	1.8065	0.0144
1.5168							
20.0856	20.0849	20.0843	20.0839	20.0837	20.0837	1.5167	8363.7920
1.9194	1.9115	1.9035	1.8956	1.8876	1.8797	1.8717	1.8638
1.8558	1.8479	1.8400	1.8320	1.8241	1.8162	1.8083	0.0145
1.5201							
20.1297	20.1289	20.1284	20.1280	20.1278	20.1278	1.5200	8447.4297
1.9194	1.9116	1.9038	1.8960	1.8881	1.8803	1.8725	1.8647
1.8568	1.8490	1.8412	1.8334	1.8256	1.8178	1.8101	0.0145
1.5234							
20.1730	20.1723	20.1717	20.1713	20.1712	20.1712	1.5233	8531.0674
1.9194	1.9117	1.9040	1.8963	1.8886	1.8809	1.8732	1.8655
1.8578	1.8502	1.8425	1.8348	1.8271	1.8195	1.8118	0.0145
1.5266							
20.2157	20.2149	20.2144	20.2140	20.2138	20.2138	1.5265	8614.7051
1.9194	1.9119	1.9043	1.8967	1.8891	1.8815	1.8740	1.8664

1.8588	1.8513	1.8437	1.8361	1.8286	1.8211	1.8135	0.0145
1.5298							
20.2576	20.2569	20.2564	20.2560	20.2558	20.2558	1.5297	8698.3438
1.9194	1.9120	1.9045	1.8971	1.8896	1.8821	1.8747	1.8672
1.8598	1.8523	1.8449	1.8375	1.8300	1.8226	1.8152	0.0145
1.5329							
20.2989	20.2982	20.2977	20.2973	20.2972	20.2972	1.5328	8781.9814
1.9194	1.9121	1.9048	1.8974	1.8901	1.8827	1.8754	1.8681
1.8607	1.8534	1.8461	1.8388	1.8314	1.8241	1.8168	0.0145
1.5360							
20.3396	20.3389	20.3384	20.3380	20.3378	20.3378	1.5359	8865.6191
1.9194	1.9122	1.9050	1.8978	1.8905	1.8833	1.8761	1.8689
1.8616	1.8544	1.8472	1.8400	1.8328	1.8256	1.8185	0.0145
1.5390							
20.3796	20.3789	20.3784	20.3780	20.3779	20.3779	1.5389	8949.2568
1.9194	1.9123	1.9052	1.8981	1.8910	1.8839	1.8768	1.8697
1.8626	1.8555	1.8484	1.8413	1.8342	1.8271	1.8200	0.0145
1.5419							
20.4190	20.4183	20.4178	20.4175	20.4173	20.4173	1.5419	9032.8945
1.9194	1.9124	1.9054	1.8984	1.8914	1.8844	1.8774	1.8704
1.8634	1.8565	1.8495	1.8425	1.8355	1.8286	1.8216	0.0146
1.5449							
20.4577	20.4571	20.4566	20.4562	20.4561	20.4561	1.5448	9116.5332
1.9194	1.9126	1.9057	1.8988	1.8919	1.8850	1.8781	1.8712
1.8643	1.8574	1.8506	1.8437	1.8368	1.8300	1.8231	0.0146
1.5478							
20.4959	20.4953	20.4948	20.4944	20.4943	20.4943	1.5477	9200.1709

```
All data are checked successfully !!!
Re-check all data entered
------------------------------------------------------------
Temperature of storage environment incelsius =25.00
Relative humidity of storage environment in % =90.00
Absolute humidity of storage environment ingH20/gAir =.0183
Diffusion coefficient of packaging materialin 10^-7 cm^2/sec =0.020
Henry constant of packaging material in(gH2O/cm^3 PKG)/(gH2O/cm^3 Air) =   125.12
000
Thickness of packaging material in cm =   0.02300
Surface area of packaging material in cm^2 =   3.78000
Volume of packaging material in cm^3 =   0.80000
Diffusion coefficient of product in 10^-5cm^2/sec =   0.11790
Initial moisture content in gH2O/100g dryproduct =0.00
Critical moisture content in gH2O/100g dryproduct =2.00
Dry weight of product in g =    0.40770
Chemical reaction rate =   0.0
Chemical reaction order =   0.0
Aw/M=-.1790E+01 Aw^2 + 0.1922E+01 Aw+ 0.6400E-01
Radius of product in cm =    0.50000
Thickness of product (Only Plate shape) incm =   0.39200
-----------------------------------------------------------------
          Hit any key to continue.....
-----------------------------------------------------------------
INITIAL CONCENTRATION
-----------------------------------------------------------------
Concentration of outside environment (CE) =  0.01938  g/L
Concentration of outside surface of PKG(CLE) =  2.42433  g/L
Concentration of inside surface of PKG(CLH) =  0.00002  g/L
Concentration of headspace (CH) =  0.00000  g/L
Concentration of outside surface of product(CRH) =  0.00132  g/L
-----------------------------------------------------------------
DIMENSSIONLESS CONSTANT
-----------------------------------------------------------------
Q=0.1260E-02
G=0.1700E-02
A1=0.1815E-04
B1=0.2127E-03
S=0.2215E+01
X=0.9000E+03
 =  13
-----------------------------------------------------------------
          Hit any key to continue ......
-----------------------------------------------------------------
    Enter the number of time to calculateconcentrations at once.

         <NOTICE !!!  It must be over 200 and be times of 200>
-----------------------------------------------------------------
```

(Plate Shape)
Each step is 137000. steps (84.3120hrs)
<# of the divided shell of product is 5

CLE CRH	CL1 CR1	CL2 CR2	CL3 CR3	CL4 CR4	CLH CRC	CH GAIN	Meq TIME(hrs)
2.4243	2.2386	2.0528	1.8670	1.6813	1.4956	1.3099	1.1243
0.9387	0.7532	0.5678	0.3824	0.1971	0.0118	0.0001	0.0607
0.8037	0.7879	0.7761	0.7682	0.7642	0.7642	0.0586	84.3120
2.4243	2.2399	2.0554	1.8710	1.6866	1.5023	1.3179	1.1337
0.9495	0.7653	0.5813	0.3973	0.2135	0.0297	0.0002	0.1299
1.7200	1.7043	1.6925	1.6847	1.6808	1.6808	0.1278	168.6240
2.4243	2.2417	2.0591	1.8765	1.6939	1.5114	1.3289	1.1466
0.9643	0.7821	0.6000	0.4181	0.2363	0.0546	0.0004	0.1984
2.6272	2.6117	2.6001	2.5923	2.5884	2.5884	0.1963	252.9361
2.4243	2.2443	2.0643	1.8843	1.7044	1.5246	1.3448	1.1652
0.9857	0.8063	0.6271	0.4481	0.2693	0.0908	0.0007	0.2659
3.5213	3.5061	3.4947	3.4871	3.4833	3.4833	0.2639	337.2481
2.4243	2.2482	2.0721	1.8961	1.7202	1.5443	1.3687	1.1931
1.0178	0.8427	0.6679	0.4933	0.3191	0.1452	0.0012	0.3320
4.3960	4.3811	4.3700	4.3626	4.3589	4.3589	0.3300	421.5601
2.4243	2.2542	2.0841	1.9141	1.7442	1.5744	1.4049	1.2357
1.0667	0.8981	0.7299	0.5621	0.3947	0.2280	0.0018	0.3958
5.2408	5.2266	5.2160	5.2088	5.2053	5.2053	0.3939	505.8722
2.4243	2.2628	2.1013	1.9399	1.7788	1.6178	1.4571	1.2968
1.1369	0.9774	0.8185	0.6601	0.5024	0.3455	0.0028	0.4563
6.0426	6.0292	6.0192	6.0125	6.0092	6.0092	0.4545	590.1841
2.4243	2.2736	2.1229	1.9723	1.8220	1.6719	1.5221	1.3728
1.2239	1.0755	0.9277	0.7806	0.6342	0.4886	0.0039	0.5128
6.7904	6.7780	6.7687	6.7625	6.7594	6.7594	0.5111	674.4962
2.4243	2.2850	2.1457	2.0065	1.8676	1.7289	1.5905	1.4525
1.3150	1.1780	1.0415	0.9057	0.7706	0.6363	0.0051	0.5649
7.4812	7.4698	7.4612	7.4555	7.4526	7.4526	0.5634	758.8082
2.4243	2.2957	2.1671	2.0387	1.9104	1.7823	1.6546	1.5271
1.4001	1.2736	1.1476	1.0222	0.8974	0.7733	0.0062	0.6131
8.1188	8.1082	8.1003	8.0950	8.0924	8.0924	0.6117	843.1202
2.4243	2.3052	2.1861	2.0672	1.9483	1.8297	1.7114	1.5933
1.4756	1.3584	1.2415	1.1252	1.0095	0.8943	0.0071	0.6577
8.7092	8.6994	8.6920	8.6871	8.6847	8.6847	0.6564	927.4323
2.4243	2.3135	2.2027	2.0920	1.9814	1.8710	1.7608	1.6509
1.5413	1.4321	1.3233	1.2149	1.1069	0.9995	0.0080	0.6992
9.2586	9.2495	9.2426	9.2381	9.2358	9.2358	0.6980	1011.7443
2.4243	2.3207	2.2171	2.1135	2.0101	1.9069	1.8038	1.7010
1.5984	1.4962	1.3942	1.2927	1.1916	1.0910	0.0087	0.7380
9.7725	9.7639	9.7575	9.7532	9.7511	9.7511	0.7368	1096.0563
2.4243	2.3270	2.2296	2.1323	2.0352	1.9381	1.8413	1.7446
1.6482	1.5520	1.4562	1.3607	1.2655	1.1708	0.0094	0.7744
10.2553	10.2473	10.2412	10.2372	10.2352	10.2352	0.7734	1180.3683
2.4243	2.3325	2.2406	2.1489	2.0572	1.9656	1.8742	1.7829
1.6919	1.6011	1.5106	1.4204	1.3304	1.2409	0.0099	0.8088
10.7109	10.7033	10.6976	10.6938	10.6919	10.6919	0.8078	1264.6804
2.4243	2.3373	2.2504	2.1634	2.0766	1.9899	1.9033	1.8168
1.7306	1.6445	1.5587	1.4732	1.3879	1.3030	0.0104	0.8414
11.1424	11.1352	11.1298	11.1261	11.1243	11.1243	0.8405	1348.9923
2.4243	2.3417	2.2590	2.1764	2.0939	2.0115	1.9292	1.8470
1.7650	1.6832	1.6016	1.5203	1.4392	1.3583	0.0109	0.8724
11.5525	11.5456	11.5404	11.5370	11.5353	11.5353	0.8715	1433.3044
2.4243	2.3456	2.2668	2.1881	2.1095	2.0309	1.9525	1.8741
1.7960	1.7179	1.6401	1.5625	1.4852	1.4080	0.0113	0.9019

11.9432	11.9367	11.9317	11.9285	11.9268	11.9268	0.9010	1517.6163
2.4243	2.3491	2.2738	2.1986	2.1235	2.0484	1.9734	1.8986
1.8239	1.7493	1.6749	1.6007	1.5267	1.4529	0.0116	0.9301
12.3166	12.3104	12.3057	12.3025	12.3009	12.3009	0.9293	1601.9285
2.4243	2.3523	2.2802	2.2082	2.1362	2.0643	1.9925	1.9208
1.8492	1.7778	1.7065	1.6354	1.5644	1.4937	0.0119	0.9571
12.6743	12.6682	12.6637	12.6607	12.6592	12.6592	0.9563	1686.2404
2.4243	2.3552	2.2860	2.2169	2.1478	2.0788	2.0099	1.9410
1.8723	1.8037	1.7353	1.6670	1.5989	1.5310	0.0122	0.9830
13.0175	13.0117	13.0074	13.0045	13.0030	13.0030	0.9823	1770.5525
2.4243	2.3578	2.2913	2.2249	2.1585	2.0921	2.0258	1.9596
1.8935	1.8275	1.7617	1.6960	1.6305	1.5651	0.0125	1.0079
13.3475	13.3420	13.3378	13.3350	13.3336	13.3336	1.0072	1854.8646
2.4243	2.3603	2.2962	2.2322	2.1683	2.1043	2.0405	1.9767
1.9130	1.8495	1.7860	1.7227	1.6596	1.5966	0.0128	1.0319
13.6654	13.6601	13.6560	13.6533	13.6520	13.6520	1.0312	1939.1765
2.4243	2.3625	2.3008	2.2390	2.1773	2.1156	2.0540	1.9925
1.9311	1.8698	1.8085	1.7474	1.6865	1.6257	0.0130	1.0551
13.9721	13.9669	13.9630	13.9604	13.9591	13.9591	1.0544	2023.4886
2.4243	2.3646	2.3050	2.2453	2.1857	2.1261	2.0666	2.0072
1.9478	1.8886	1.8294	1.7704	1.7114	1.6527	0.0132	1.0775
14.2683	14.2633	14.2595	14.2570	14.2558	14.2558	1.0768	2107.8005
2.4243	2.3666	2.3089	2.2512	2.1935	2.1359	2.0783	2.0208
1.9634	1.9061	1.8488	1.7917	1.7347	1.6778	0.0134	1.0991
14.5548	14.5500	14.5464	14.5439	14.5427	14.5427	1.0985	2192.1125
2.4243	2.3684	2.3125	2.2567	2.2008	2.1450	2.0893	2.0336
1.9780	1.9224	1.8670	1.8116	1.7564	1.7013	0.0136	1.1201
14.8323	14.8276	14.8241	14.8218	14.8206	14.8206	1.1194	2276.4248
2.4243	2.3701	2.3160	2.2618	2.2077	2.1536	2.0995	2.0455
1.9916	1.9377	1.8840	1.8303	1.7767	1.7233	0.0138	1.1404
15.1013	15.0968	15.0934	15.0911	15.0899	15.0899	1.1398	2360.7366
2.4243	2.3717	2.3192	2.2666	2.2141	2.1616	2.1091	2.0567
2.0044	1.9521	1.8999	1.8478	1.7958	1.7439	0.0139	1.1601
15.3624	15.3580	15.3546	15.3524	15.3513	15.3513	1.1595	2445.0486
2.4243	2.3733	2.3222	2.2711	2.2201	2.1691	2.1181	2.0672
2.0164	1.9656	1.9149	1.8643	1.8138	1.7633	0.0141	1.1792
15.6159	15.6117	15.6084	15.6063	15.6052	15.6052	1.1787	2529.3608
2.4243	2.3747	2.3250	2.2754	2.2258	2.1762	2.1267	2.0772
2.0277	1.9784	1.9291	1.8798	1.8307	1.7817	0.0142	1.1979
15.8625	15.8583	15.8552	15.8531	15.8520	15.8520	1.1973	2613.6729
2.4243	2.3760	2.3277	2.2794	2.2311	2.1829	2.1347	2.0865
2.0384	1.9904	1.9424	1.8945	1.8467	1.7990	0.0144	1.2160
16.1023	16.0982	16.0952	16.0932	16.0921	16.0921	1.2154	2697.9846
2.4243	2.3773	2.3303	2.2832	2.2362	2.1893	2.1423	2.0954
2.0486	2.0018	1.9551	1.9084	1.8619	1.8154	0.0145	1.2336
16.3359	16.3319	16.3289	16.3269	16.3260	16.3260	1.2331	2782.2966
2.4243	2.3785	2.3327	2.2868	2.2411	2.1953	2.1495	2.1039
2.0582	2.0126	1.9671	1.9216	1.8762	1.8309	0.0146	1.2508
16.5634	16.5596	16.5567	16.5547	16.5538	16.5538	1.2503	2866.6089
2.4243	2.3796	2.3350	2.2903	2.2456	2.2010	2.1564	2.1119
2.0673	2.0229	1.9785	1.9341	1.8899	1.8457	0.0148	1.2675
16.7853	16.7815	16.7787	16.7768	16.7759	16.7759	1.2670	2950.9209
2.4243	2.3807	2.3371	2.2936	2.2500	2.2064	2.1629	2.1195
2.0760	2.0327	1.9893	1.9461	1.9029	1.8597	0.0149	1.2839
17.0018	16.9981	16.9953	16.9935	16.9926	16.9926	1.2834	3035.2327
2.4243	2.3818	2.3392	2.2967	2.2541	2.2116	2.1692	2.1267
2.0843	2.0420	1.9997	1.9574	1.9152	1.8731	0.0150	1.2999
17.2131	17.2095	17.2068	17.2050	17.2041	17.2041	1.2994	3119.5449
2.4243	2.3828	2.3412	2.2996	2.2581	2.2166	2.1751	2.1336
2.0922	2.0508	2.0095	1.9683	1.9270	1.8859	0.0151	1.3154

17.4195	17.4160	17.4134	17.4116	17.4107	17.4107	1.3150	3203.8569
2.4243	2.3837	2.3431	2.3025	2.2619	2.2213	2.1808	2.1402
2.0998	2.0593	2.0189	1.9786	1.9383	1.8981	0.0152	1.3307
17.6212	17.6178	17.6152	17.6135	17.6126	17.6126	1.3302	3288.1689
2.4243	2.3846	2.3449	2.3052	2.2655	2.2258	2.1862	2.1466
2.1070	2.0674	2.0280	1.9885	1.9491	1.9098	0.0153	1.3456
17.8184	17.8151	17.8126	17.8109	17.8100	17.8100	1.3451	3372.4807
2.4243	2.3855	2.3466	2.3078	2.2690	2.2302	2.1914	2.1526
2.1139	2.0752	2.0366	1.9980	1.9595	1.9210	0.0154	1.3601
18.0113	18.0081	18.0056	18.0040	18.0031	18.0031	1.3597	3456.7930
2.4243	2.3863	2.3483	2.3103	2.2723	2.2343	2.1963	2.1584
2.1205	2.0827	2.0449	2.0071	1.9694	1.9317	0.0154	1.3744
18.2001	18.1969	18.1945	18.1929	18.1921	18.1921	1.3740	3541.1050
2.4243	2.3871	2.3499	2.3127	2.2755	2.2383	2.2011	2.1640
2.1269	2.0898	2.0528	2.0158	1.9789	1.9420	0.0155	1.3883
18.3850	18.3818	18.3795	18.3779	18.3771	18.3771	1.3879	3625.4170
2.4243	2.3879	2.3514	2.3150	2.2785	2.2421	2.2057	2.1693
2.1330	2.0967	2.0604	2.0242	1.9880	1.9519	0.0156	1.4020
18.5660	18.5629	18.5606	18.5591	18.5583	18.5583	1.4016	3709.7292
2.4243	2.3886	2.3529	2.3172	2.2815	2.2458	2.2101	2.1745
2.1389	2.1033	2.0678	2.0323	1.9968	1.9614	0.0157	1.4154
18.7434	18.7404	18.7381	18.7366	18.7359	18.7359	1.4150	3794.0410
2.4243	2.3893	2.3543	2.3193	2.2843	2.2493	2.2144	2.1794
2.1445	2.1097	2.0748	2.0400	2.0053	1.9706	0.0157	1.4285
18.9173	18.9143	18.9121	18.9106	18.9099	18.9099	1.4282	3878.3530
2.4243	2.3900	2.3557	2.3213	2.2870	2.2527	2.2185	2.1842
2.1500	2.1158	2.0816	2.0475	2.0134	1.9794	0.0158	1.4414
19.0878	19.0849	19.0827	19.0812	19.0805	19.0805	1.4410	3962.6653
2.4243	2.3907	2.3570	2.3233	2.2897	2.2560	2.2224	2.1888
2.1552	2.1217	2.0882	2.0547	2.0213	1.9879	0.0159	1.4540
19.2550	19.2521	19.2500	19.2486	19.2479	19.2479	1.4537	4046.9773
2.4243	2.3913	2.3583	2.3252	2.2922	2.2592	2.2262	2.1932
2.1603	2.1274	2.0945	2.0617	2.0289	1.9961	0.0160	1.4664
19.4190	19.4163	19.4142	19.4128	19.4121	19.4121	1.4661	4131.2891
2.4243	2.3919	2.3595	2.3271	2.2947	2.2623	2.2299	2.1975
2.1652	2.1329	2.1006	2.0684	2.0362	2.0040	0.0160	1.4786
19.5801	19.5773	19.5753	19.5739	19.5732	19.5732	1.4782	4215.6011
2.4243	2.3925	2.3607	2.3288	2.2970	2.2652	2.2334	2.2017
2.1699	2.1382	2.1065	2.0749	2.0433	2.0117	0.0161	1.4905
19.7382	19.7355	19.7334	19.7321	19.7314	19.7314	1.4902	4299.9136
2.4243	2.3931	2.3618	2.3306	2.2993	2.2681	2.2369	2.2057
2.1745	2.1434	2.1122	2.0812	2.0501	2.0191	0.0161	1.5023
19.8934	19.8907	19.8888	19.8874	19.8868	19.8868	1.5019	4384.2251
2.4243	2.3936	2.3629	2.3322	2.3015	2.2709	2.2402	2.2095
2.1789	2.1483	2.1178	2.0872	2.0567	2.0263	0.0162	1.5138
20.0459	20.0433	20.0413	20.0400	20.0394	20.0394	1.5134	4468.5371
2.4243	2.3942	2.3640	2.3338	2.3037	2.2735	2.2434	2.2133
2.1832	2.1531	2.1231	2.0931	2.0631	2.0332	0.0163	1.5251
20.1957	20.1932	20.1912	20.1900	20.1893	20.1893	1.5247	4552.8496
2.4243	2.3947	2.3650	2.3354	2.3058	2.2761	2.2465	2.2169
2.1874	2.1578	2.1283	2.0988	2.0693	2.0399	0.0163	1.5362
20.3429	20.3404	20.3386	20.3373	20.3367	20.3367	1.5359	4637.1616
2.4243	2.3952	2.3660	2.3369	2.3078	2.2786	2.2495	2.2205
2.1914	2.1623	2.1333	2.1043	2.0754	2.0464	0.0164	1.5471
20.4877	20.4852	20.4834	20.4821	20.4815	20.4815	1.5468	4721.4731
2.4243	2.3957	2.3670	2.3384	2.3097	2.2811	2.2525	2.2239
2.1953	2.1667	2.1382	2.1097	2.0812	2.0528	0.0164	1.5579
20.6300	20.6276	20.6258	20.6246	20.6240	20.6240	1.5576	4805.7856
2.4243	2.3961	2.3680	2.3398	2.3116	2.2835	2.2553	2.2272
2.1991	2.1710	2.1429	2.1149	2.0869	2.0589	0.0165	1.5685

20.7700	20.7676	20.7658	20.7646	20.7640	20.7640	1.5681	4890.0972
2.4243	2.3966	2.3689	2.3412	2.3135	2.2858	2.2581	2.2304
2.2027	2.1751	2.1475	2.1199	2.0924	2.0649	0.0165	1.5788
20.9077	20.9053	20.9036	20.9024	20.9018	20.9018	1.5785	4974.4097
2.4243	2.3971	2.3698	2.3425	2.3152	2.2880	2.2607	2.2335
2.2063	2.1791	2.1520	2.1248	2.0977	2.0706	0.0165	1.5891
21.0431	21.0408	21.0391	21.0379	21.0374	21.0374	1.5888	5058.7217
2.4243	2.3975	2.3706	2.3438	2.3170	2.2902	2.2634	2.2366
2.2098	2.1830	2.1563	2.1296	2.1029	2.0763	0.0166	1.5991
21.1764	21.1742	21.1725	21.1713	21.1708	21.1708	1.5988	5143.0332
2.4243	2.3979	2.3715	2.3451	2.3187	2.2923	2.2659	2.2395
2.2132	2.1868	2.1605	2.1342	2.1080	2.0817	0.0166	1.6091
21.3076	21.3054	21.3037	21.3026	21.3021	21.3021	1.6088	5227.3457
2.4243	2.3983	2.3723	2.3463	2.3203	2.2943	2.2683	2.2424
2.2164	2.1905	2.1646	2.1387	2.1129	2.0870	0.0167	1.6188
21.4368	21.4346	21.4330	21.4319	21.4313	21.4313	1.6185	5311.6577
2.4243	2.3987	2.3731	2.3475	2.3219	2.2963	2.2707	2.2452
2.2196	2.1941	2.1686	2.1431	2.1177	2.0922	0.0167	1.6284
21.5640	21.5618	21.5602	21.5591	21.5586	21.5586	1.6281	5395.9692
2.4243	2.3991	2.3739	2.3487	2.3235	2.2983	2.2731	2.2479
2.2227	2.1976	2.1725	2.1474	2.1223	2.0973	0.0168	1.6379
21.6893	21.6871	21.6855	21.6844	21.6839	21.6839	1.6376	5480.2817
2.4243	2.3995	2.3747	2.3498	2.3250	2.3002	2.2754	2.2506
2.2258	2.2010	2.1763	2.1515	2.1268	2.1022	0.0168	1.6472
21.8126	21.8105	21.8089	21.8079	21.8074	21.8074	1.6469	5564.5933
2.4243	2.3999	2.3754	2.3509	2.3265	2.3020	2.2776	2.2531
2.2287	2.2043	2.1799	2.1556	2.1313	2.1069	0.0168	1.6564
21.9342	21.9321	21.9305	21.9295	21.9290	21.9290	1.6561	5648.9058
2.4243	2.4002	2.3761	2.3520	2.3279	2.3038	2.2797	2.2557
2.2316	2.2076	2.1835	2.1595	2.1356	2.1116	0.0169	1.6654
22.0539	22.0519	22.0503	22.0493	22.0488	22.0488	1.6651	5733.2178
2.4243	2.4006	2.3768	2.3531	2.3293	2.3056	2.2818	2.2581
2.2344	2.2107	2.1870	2.1634	2.1398	2.1162	0.0169	1.6743
22.1719	22.1699	22.1684	22.1674	22.1669	22.1669	1.6741	5817.5293
2.4243	2.4009	2.3775	2.3541	2.3307	2.3073	2.2839	2.2605
2.2371	2.2138	2.1905	2.1671	2.1439	2.1206	0.0169	1.6831
22.2882	22.2862	22.2847	22.2838	22.2833	22.2833	1.6828	5901.8418
2.4243	2.4012	2.3782	2.3551	2.3320	2.3089	2.2859	2.2628
2.2398	2.2168	2.1938	2.1708	2.1479	2.1249	0.0170	1.6918
22.4029	22.4009	22.3994	22.3985	22.3980	22.3980	1.6915	5986.1538
2.4243	2.4016	2.3788	2.3561	2.3333	2.3106	2.2878	2.2651
2.2424	2.2197	2.1970	2.1744	2.1518	2.1291	0.0170	1.7003
22.5159	22.5140	22.5125	22.5116	22.5111	22.5111	1.7000	6070.4653
2.4243	2.4019	2.3795	2.3570	2.3346	2.3122	2.2898	2.2673
2.2450	2.2226	2.2002	2.1779	2.1556	2.1333	0.0170	1.7087
22.6273	22.6254	22.6240	22.6231	22.6226	22.6226	1.7085	6154.7778
2.4243	2.4022	2.3801	2.3580	2.3358	2.3137	2.2916	2.2695
2.2474	2.2254	2.2033	2.1813	2.1593	2.1373	0.0171	1.7170
22.7372	22.7354	22.7340	22.7330	22.7326	22.7326	1.7168	6239.0898
2.4243	2.4025	2.3807	2.3589	2.3370	2.3152	2.2934	2.2716
2.2499	2.2281	2.2064	2.1846	2.1629	2.1412	0.0171	1.7252
22.8456	22.8438	22.8424	22.8415	22.8410	22.8410	1.7250	6323.4019
2.4243	2.4028	2.3813	2.3598	2.3382	2.3167	2.2952	2.2737
2.2522	2.2308	2.2093	2.1879	2.1665	2.1451	0.0171	1.7333
22.9526	22.9507	22.9494	22.9484	22.9480	22.9480	1.7330	6407.7139
2.4243	2.4031	2.3819	2.3606	2.3394	2.3182	2.2970	2.2758
2.2546	2.2334	2.2122	2.1911	2.1699	2.1488	0.0172	1.7412
23.0580	23.0562	23.0549	23.0540	23.0535	23.0535	1.7410	6492.0259
2.4243	2.4034	2.3824	2.3615	2.3405	2.3196	2.2987	2.2777
2.2568	2.2359	2.2150	2.1942	2.1733	2.1525	0.0172	1.7491

23.1621	23.1603	23.1590	23.1581	23.1577	23.1577	1.7489	6576.3379
2.4243	2.4037	2.3830	2.3623	2.3416	2.3210	2.3003	2.2797
2.2590	2.2384	2.2178	2.1972	2.1767	2.1561	0.0172	1.7568
23.2648	23.2630	23.2617	23.2608	23.2604	23.2604	1.7566	6660.6499
2.4243	2.4039	2.3835	2.3631	2.3427	2.3223	2.3020	2.2816
2.2612	2.2409	2.2205	2.2002	2.1799	2.1596	0.0173	1.7645
23.3661	23.3644	23.3631	23.3622	23.3618	23.3618	1.7643	6744.9614
2.4243	2.4042	2.3841	2.3639	2.3438	2.3237	2.3035	2.2834
2.2633	2.2433	2.2232	2.2031	2.1831	2.1631	0.0173	1.7721
23.4662	23.4644	23.4632	23.4623	23.4619	23.4619	1.7718	6829.2739
2.4243	2.4045	2.3846	2.3647	2.3448	2.3250	2.3051	2.2853
2.2654	2.2456	2.2258	2.2060	2.1862	2.1664	0.0173	1.7795
23.5649	23.5632	23.5619	23.5611	23.5607	23.5607	1.7793	6913.5859
2.4243	2.4047	2.3851	2.3655	2.3458	2.3262	2.3066	2.2870
2.2675	2.2479	2.2283	2.2088	2.1892	2.1697	0.0173	1.7869
23.6624	23.6607	23.6594	23.6586	23.6582	23.6582	1.7867	6997.8979
2.4243	2.4050	2.3856	2.3662	2.3468	2.3275	2.3081	2.2888
2.2694	2.2501	2.2308	2.2115	2.1922	2.1730	0.0174	1.7941
23.7586	23.7569	23.7557	23.7549	23.7545	23.7545	1.7939	7082.2100
2.4243	2.4052	2.3861	2.3669	2.3478	2.3287	2.3096	2.2905
2.2714	2.2523	2.2333	2.2142	2.1952	2.1761	0.0174	1.8013
23.8536	23.8520	23.8508	23.8499	23.8495	23.8495	1.8011	7166.5225
2.4243	2.4054	2.3866	2.3677	2.3488	2.3299	2.3110	2.2922
2.2733	2.2545	2.2356	2.2168	2.1980	2.1792	0.0174	1.8084
23.9474	23.9458	23.9446	23.9438	23.9434	23.9434	1.8082	7250.8340
2.4243	2.4057	2.3870	2.3684	2.3497	2.3311	2.3124	2.2938
2.2752	2.2566	2.2380	2.2194	2.2008	2.1823	0.0174	1.8154
24.0401	24.0385	24.0373	24.0365	24.0361	24.0361	1.8152	7335.1460
2.4243	2.4059	2.3875	2.3691	2.3506	2.3322	2.3138	2.2954
2.2770	2.2587	2.2403	2.2219	2.2036	2.1853	0.0175	1.8223
24.1316	24.1300	24.1288	24.1281	24.1277	24.1277	1.8221	7419.4585
2.4243	2.4061	2.3879	2.3697	2.3515	2.3334	2.3152	2.2970
2.2788	2.2607	2.2425	2.2244	2.2063	2.1882	0.0175	1.8291
24.2220	24.2204	24.2193	24.2185	24.2181	24.2181	1.8289	7503.7700
2.4243	2.4064	2.3884	2.3704	2.3524	2.3345	2.3165	2.2985
2.2806	2.2627	2.2447	2.2268	2.2089	2.1911	0.0175	1.8359
24.3113	24.3098	24.3086	24.3078	24.3075	24.3075	1.8357	7588.0820
2.4243	2.4066	2.3888	2.3711	2.3533	2.3355	2.3178	2.3001
2.2823	2.2646	2.2469	2.2292	2.2115	2.1939	0.0175	1.8425
24.3995	24.3980	24.3969	24.3961	24.3957	24.3957	1.8423	7672.3945
2.4243	2.4068	2.3892	2.3717	2.3541	2.3366	2.3191	2.3016
2.2840	2.2665	2.2490	2.2316	2.2141	2.1966	0.0176	1.8491
24.4867	24.4852	24.4841	24.4833	24.4829	24.4829	1.8489	7756.7061
2.4243	2.4070	2.3897	2.3723	2.3550	2.3377	2.3203	2.3030
2.2857	2.2684	2.2511	2.2338	2.2166	2.1993	0.0176	1.8556
24.5728	24.5713	24.5702	24.5695	24.5691	24.5691	1.8554	7841.0186
2.4243	2.4072	2.3901	2.3729	2.3558	2.3387	2.3216	2.3044
2.2873	2.2702	2.2532	2.2361	2.2190	2.2020	0.0176	1.8620
24.6579	24.6564	24.6553	24.6546	24.6543	24.6543	1.8619	7925.3306
2.4243	2.4074	2.3905	2.3735	2.3566	2.3397	2.3228	2.3059
2.2889	2.2721	2.2552	2.2383	2.2214	2.2046	0.0176	1.8684
24.7420	24.7406	24.7395	24.7388	24.7384	24.7384	1.8682	8009.6421
2.4243	2.4076	2.3909	2.3741	2.3574	2.3407	2.3239	2.3072
2.2905	2.2738	2.2571	2.2405	2.2238	2.2072	0.0176	1.8747
24.8251	24.8237	24.8226	24.8219	24.8216	24.8216	1.8745	8093.9546
2.4243	2.4078	2.3912	2.3747	2.3582	2.3416	2.3251	2.3086
2.2921	2.2756	2.2591	2.2426	2.2261	2.2097	0.0177	1.8809
24.9073	24.9059	24.9048	24.9041	24.9038	24.9038	1.8807	8178.2661
2.4243	2.4080	2.3916	2.3753	2.3589	2.3426	2.3263	2.3099
2.2936	2.2773	2.2610	2.2447	2.2284	2.2121	0.0177	1.8870

24.9885	24.9871	24.9861	24.9854	24.9850	24.9850	1.8868	8262.5781
2.4243	2.4082	2.3920	2.3758	2.3597	2.3435	2.3274	2.3112
2.2951	2.2790	2.2629	2.2467	2.2306	2.2146	0.0177	1.8931
25.0688	25.0674	25.0664	25.0657	25.0654	25.0654	1.8929	8346.8906
2.4243	2.4084	2.3924	2.3764	2.3604	2.3444	2.3285	2.3125
2.2966	2.2806	2.2647	2.2488	2.2328	2.2169	0.0177	1.8991
25.1482	25.1468	25.1458	25.1451	25.1448	25.1448	1.8989	8431.2021
2.4243	2.4085	2.3927	2.3769	2.3611	2.3453	2.3296	2.3138
2.2980	2.2822	2.2665	2.2507	2.2350	2.2193	0.0177	1.9050
25.2266	25.2253	25.2243	25.2236	25.2233	25.2233	1.9048	8515.5146
2.4243	2.4087	2.3931	2.3775	2.3618	2.3462	2.3306	2.3150
2.2994	2.2838	2.2683	2.2527	2.2371	2.2216	0.0178	1.9109
25.3042	25.3029	25.3019	25.3013	25.3009	25.3009	1.9107	8599.8271
2.4243	2.4089	2.3934	2.3780	2.3625	2.3471	2.3317	2.3162
2.3008	2.2854	2.2700	2.2546	2.2392	2.2239	0.0178	1.9167
25.3810	25.3797	25.3787	25.3780	25.3777	25.3777	1.9165	8684.1387
2.4243	2.4091	2.3938	2.3785	2.3632	2.3480	2.3327	2.3174
2.3022	2.2870	2.2717	2.2565	2.2413	2.2261	0.0178	1.9224
25.4569	25.4556	25.4546	25.4539	25.4536	25.4536	1.9222	8768.4502
2.4243	2.4092	2.3941	2.3790	2.3639	2.3488	2.3337	2.3186
2.3035	2.2885	2.2734	2.2583	2.2433	2.2283	0.0178	1.9280
25.5319	25.5306	25.5297	25.5290	25.5287	25.5287	1.9279	8852.7627
2.4243	2.4094	2.3944	2.3795	2.3646	2.3496	2.3347	2.3198
2.3049	2.2900	2.2751	2.2602	2.2453	2.2304	0.0178	1.9337
25.6061	25.6048	25.6039	25.6033	25.6029	25.6029	1.9335	8937.0742
2.4243	2.4096	2.3948	2.3800	2.3652	2.3505	2.3357	2.3209
2.3062	2.2914	2.2767	2.2620	2.2472	2.2325	0.0178	1.9392
25.6795	25.6783	25.6773	25.6767	25.6764	25.6764	1.9390	9021.3867
2.4243	2.4097	2.3951	2.3805	2.3659	2.3513	2.3366	2.3220
2.3075	2.2929	2.2783	2.2637	2.2492	2.2346	0.0179	1.9447
25.7521	25.7509	25.7500	25.7493	25.7490	25.7490	1.9445	9105.6992
2.4243	2.4099	2.3954	2.3810	2.3665	2.3520	2.3376	2.3232
2.3087	2.2943	2.2799	2.2654	2.2510	2.2367	0.0179	1.9501
25.8240	25.8227	25.8218	25.8212	25.8209	25.8209	1.9499	9190.0107
2.4243	2.4100	2.3957	2.3814	2.3671	2.3528	2.3385	2.3242
2.3100	2.2957	2.2814	2.2672	2.2529	2.2387	0.0179	1.9555
25.8950	25.8938	25.8929	25.8923	25.8920	25.8920	1.9553	9274.3232
2.4243	2.4102	2.3960	2.3819	2.3677	2.3536	2.3394	2.3253
2.3112	2.2971	2.2829	2.2688	2.2547	2.2407	0.0179	1.9608
25.9653	25.9641	25.9632	25.9626	25.9623	25.9623	1.9606	9358.6348
2.4243	2.4103	2.3963	2.3823	2.3683	2.3543	2.3403	2.3264
2.3124	2.2984	2.2844	2.2705	2.2565	2.2426	0.0179	1.9660
26.0349	26.0337	26.0328	26.0322	26.0319	26.0319	1.9659	9442.9463
2.4243	2.4105	2.3966	2.3828	2.3689	2.3551	2.3412	2.3274
2.3136	2.2997	2.2859	2.2721	2.2583	2.2445	0.0179	1.9712
26.1037	26.1025	26.1016	26.1010	26.1007	26.1007	1.9711	9527.2588
2.4243	2.4106	2.3969	2.3832	2.3695	2.3558	2.3421	2.3284
2.3147	2.3010	2.2874	2.2737	2.2601	2.2464	0.0180	1.9764
26.1718	26.1706	26.1697	26.1692	26.1689	26.1689	1.9762	9611.5713
2.4243	2.4108	2.3972	2.3836	2.3701	2.3565	2.3430	2.3294
2.3159	2.3023	2.2888	2.2753	2.2618	2.2483	0.0180	1.9815
26.2392	26.2380	26.2371	26.2366	26.2363	26.2363	1.9813	9695.8838
2.4243	2.4109	2.3975	2.3841	2.3706	2.3572	2.3438	2.3304
2.3170	2.3036	2.2902	2.2768	2.2635	2.2501	0.0180	1.9865
26.3058	26.3047	26.3038	26.3033	26.3030	26.3030	1.9863	9780.1943
2.4243	2.4110	2.3978	2.3845	2.3712	2.3579	2.3446	2.3314
2.3181	2.3049	2.2916	2.2784	2.2651	2.2519	0.0180	1.9915
26.3718	26.3707	26.3699	26.3693	26.3690	26.3690	1.9913	9864.5068
2.4243	2.4112	2.3980	2.3849	2.3717	2.3586	2.3455	2.3323
2.3192	2.3061	2.2930	2.2799	2.2668	2.2537	0.0180	1.9964

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26.4371  26.4360  26.4352  26.4346  26.4343  26.4343   1.9963  9948.8193
--------------------------------------------------------------------------
              SHELF-LIFE OF THIS PRODUCT IS     10013.31445hrs
------------------------------------------------------------------------
FORTRAN STOP
```

APPENDIX B

APPENDIX B

Sorption Experiment of Deltasone Tablet

Table 11. Summary of sorption experiments of 20 mg Deltasone tablet at 25.0 °C

Test Number	Experimental Test	Relative Humidity Range (%)
1	SORP B1	0 - 11.50
2	SORP B2	11.50 - 15.25
3	SORP C1	15.75 - 23.20
4	SORP C2	23.20 - 27
5	SORP C3a	27.50 - 34.50
6	SORP C3b	36 - 40
7	SORP C5	40.75 - 48.80
8	SORP 6C	48.85 - 60.35
9	SORP 7Ca	60.70 - 66
10	SORP 7Cb	66 - 73.40
11	SORP C8	72.25 - 77.75
12	SORP C9	77.90 - 82.45
13	SORP 10	82.05 - 87.30
14	SORP 13	86.70 - 91.70

Table 12. Moisture sorption isotherm data for Deltasone tablet at 25.0 ° C

A_w	Absolute Tablet Weight (mg)	Tablet Weight Change (mg)	EMC (g H_2O/100 g dry product)
0	407.7421	0	0
0.115	409.2698	1.5277	0.375
0.153	409.35	1.6079	0.394
0.232	409.8798	2.1377	0.524
0.27	410.36	2.6179	0.642
0.345	410.593	2.8509	0.699
0.4	410.7729	3.0308	0.743
0.488	411.5429	3.8008	0.932
0.604	412.0246	4.2825	1.05
0.66	412.7226	4.9805	1.221
0.734	413.3085	5.5664	1.365
0.778	414.2913	6.5492	1.606
0.825	415.5057	7.7636	1.904
0.873	415.7983	8.0562	1.976
0.917	422.0713	14.3292	3.514

A_w = Water activity
EMC = Equilibrium Moisture Content

Table 13. Comparison of experimental and calculated M_t/M_∞ for tablet at 0 - 11.50% R.H. and 25.0 °C with determination of diffusion coefficient

Time (hours)	Exp. M_t/M_∞	Calculated M_t/M_∞	$T_{1/2}$ (hours)	Sum of diff.^{2}
0	0	0	1.52	0.090486
1	0.427244	0.397925	1.54	0.089439
2	0.63193	0.540453	1.58	0.087708
3	0.73483	0.653264	1.62	0.086465
4	0.785625	0.738693	1.66	0.085695
5	0.819533	0.803099	1.70	0.085376
6	0.842836	0.851632	**1.71**	**0.085365**
7	0.859789	0.888202	1.72	0.085381
8	0.873208	0.915759	1.73	0.085422
9	0.883943	0.936523	1.74	0.085491
10	0.893042	0.952169	1.75	0.085587
11	0.900242	0.963959	1.76	0.085711
12	0.906592	0.972842		
13	0.911828	0.979536		
14	0.91641	0.98458		
15	0.920665	0.988381	Diffusion	
16	0.923545	0.991245	Coeff. =	
17	0.924789	0.993403	0.004404	
18	0.925313	0.995029	cm^2/hour	
19	0.923807	0.996254		
20	0.931138	0.997178		
21	0.948616	0.997873		
22	0.955227	0.998397		
23	0.960136	0.998792		
24	0.96354	0.99909		
25	0.967467	0.999314		
26	0.973555	0.999483		
27	0.975453	0.999611		
28	0.976239	0.999707		
29	0.979577	0.999779		
30	0.979053	0.999833		
31	0.980101	0.999875		
32	0.981606	0.999905		
33	0.984094	0.999929		
34	0.987039	0.999946		
35	0.990116	0.99996		
36	0.992996	0.99997		
37	0.995352	0.999977		
38	0.997185	0.999983		
39	0.998756	0.999987		
40	1	0.99999		
40.75	1	0.999992		

Sum of diff.^{2} = sum of the difference^2 between exp. and calc.

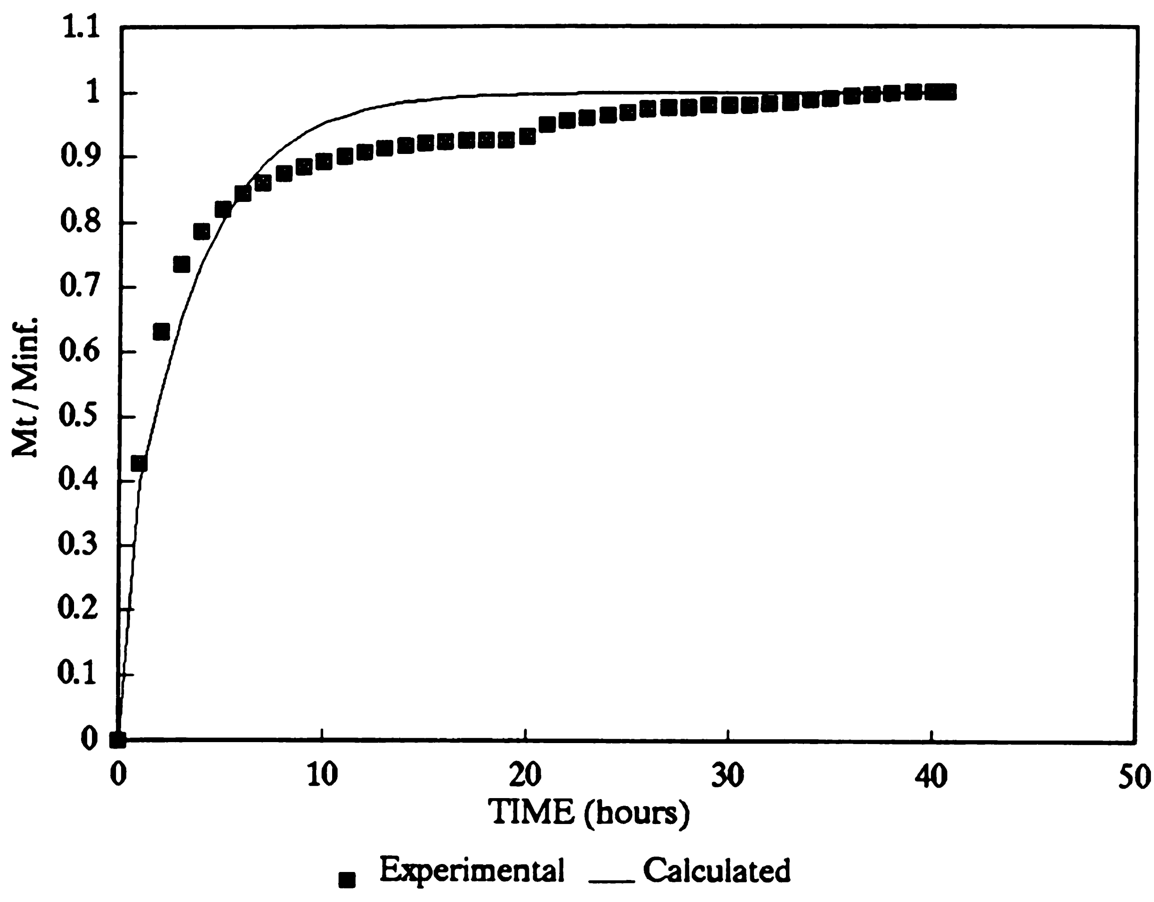

Figure 25. Comparison of experimental and calculated M_t/M_∞ for tablet at 0 - 11.50% R.H. and 25.0 ° C (SORP B1)

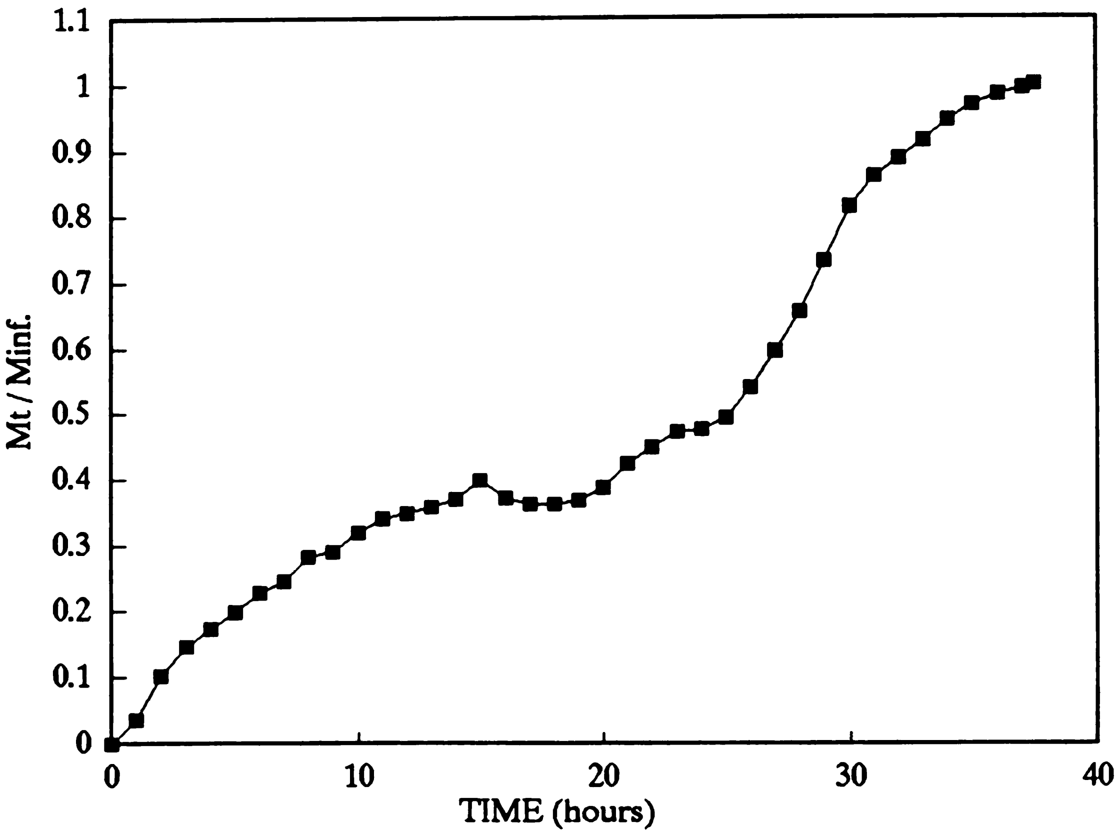

Figure 26. Experimental sorption of tablet at 11.50 - 15.25% R.H., 25.0 ° C (SORP B2)

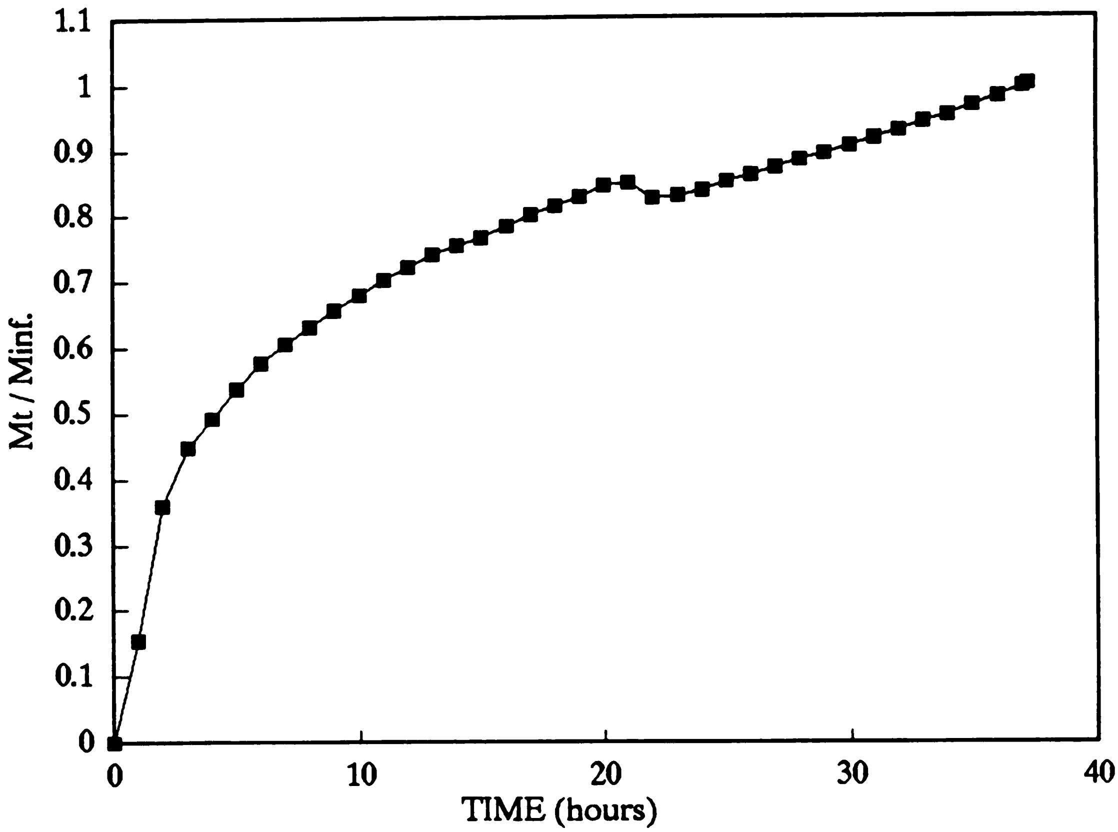

Figure 27. Experimental sorption of tablet at 15.75 - 23.20% R.H., 25.0 ° C (SORP C1)

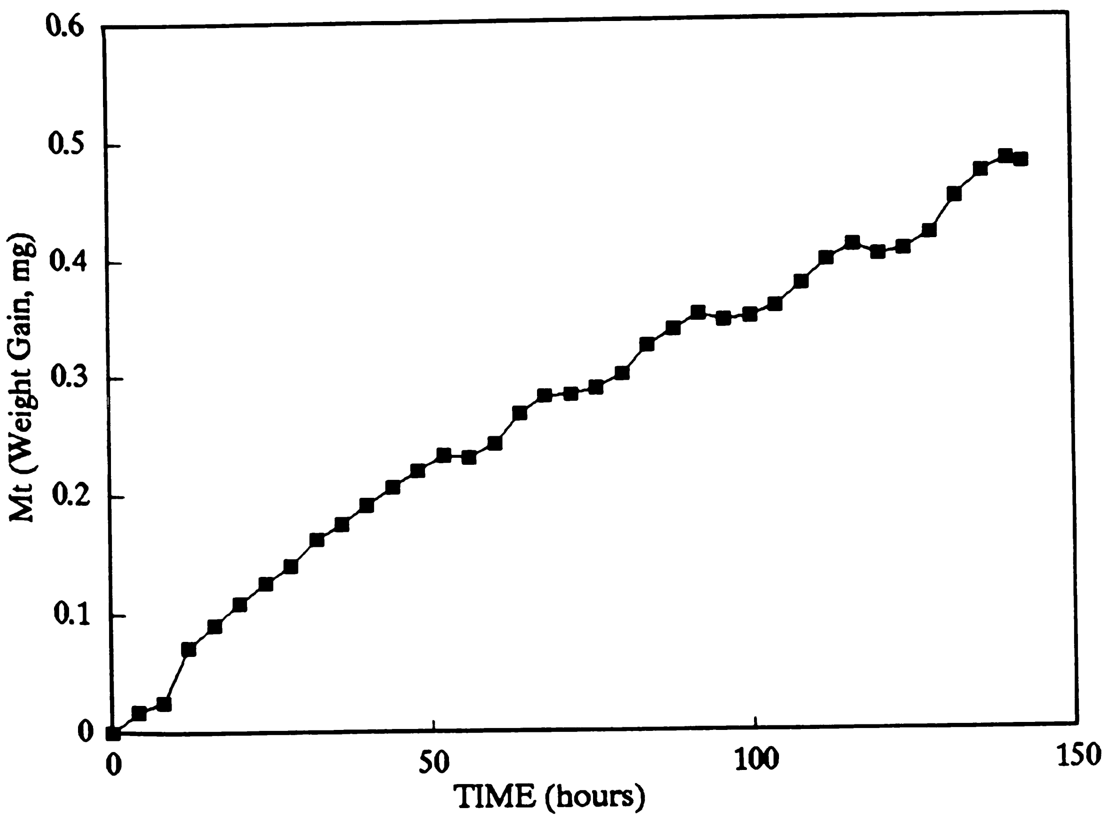

Figure 28. Experimental tablet weight gain at 23.20 - 27% R.H., 25.0 ° C (SORP C2)

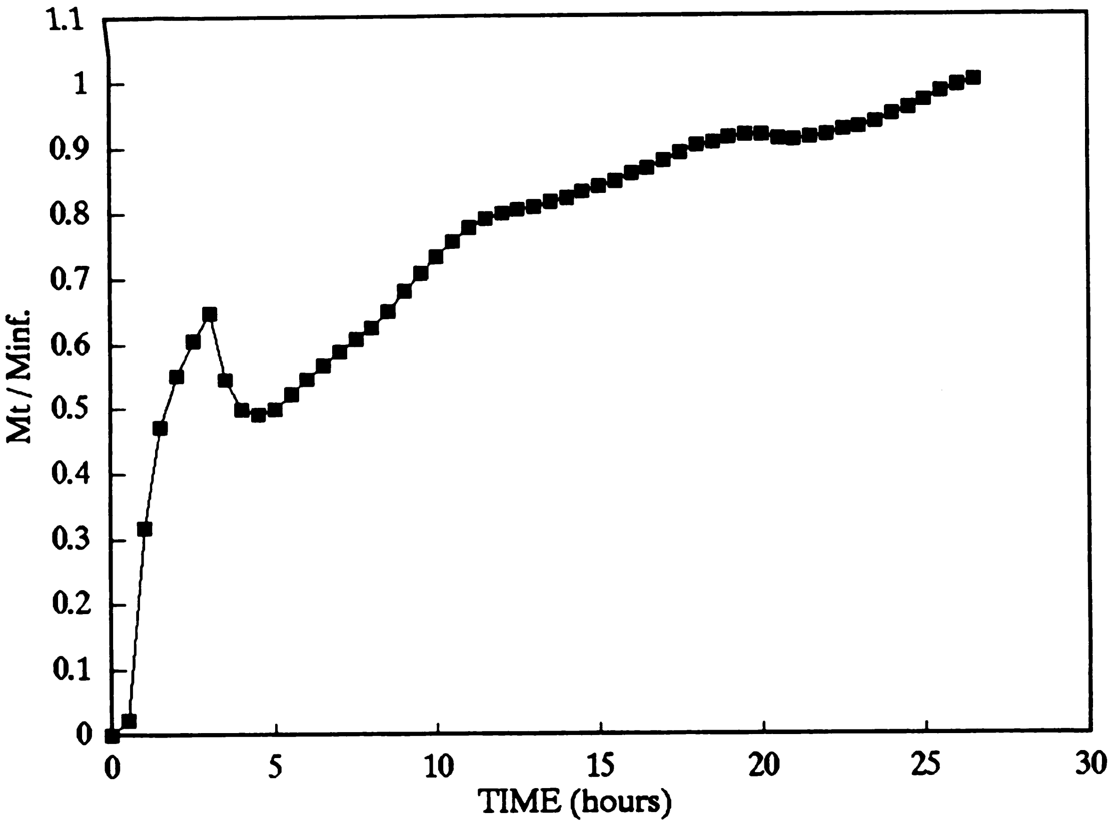

Figure 29. Experimental sorption of tablet at 27.50 - 34.50% R.H., 25.0 ° C (SORP C3a)

Table 14. Comparison of experimental and calculated M_t/M_∞ for tablet at 36 - 40% R.H. and 25.0 ^{0} C with determination of diffusion coefficient

Time (hours)	Exp. M_t/M_∞	Calculated M_t/M_∞	$T_{1/2}$ (hours)	Sum of diff.^{2}
0	0	0	2.10	0.761768
0.25	0.00603	0.299699	2.20	0.721648
0.5	0.022111	0.31119	2.30	0.695722
0.75	0.052261	0.330029	2.40	0.682854
1	0.088442	0.353041	2.45	0.68094
1.25	0.139698	0.378209	2.46	0.680894
1.5	0.18392	0.404266	2.47	0.680961
1.75	0.237186	0.430419	2.48	0.681131
2	0.281407	0.456183		
2.25	0.333668	0.481267		
2.5	0.38191	0.505505		
2.75	0.435176	0.528809		
3	0.478392	0.551144		
3.25	0.514573	0.572502		
3.5	0.539698	0.592896		
3.75	0.560804	0.612352	Diffusion	
4	0.584925	0.630899	Coeff. =	
4.25	0.60804	0.648573	0.003061	
4.5	0.634171	0.66541	cm^2/hour	
4.75	0.660302	0.681446		
5	0.681407	0.696717		
5.25	0.702513	0.711258		
5.5	0.731658	0.725104		
5.75	0.751759	0.738286		
6	0.769849	0.750837		
6.25	0.78995	0.762787		
6.5	0.80804	0.774164		
6.75	0.826131	0.784995		
7	0.842211	0.795307		
7.25	0.861307	0.805124		
7.5	0.870352	0.814471		
7.75	0.881407	0.823369		
8	0.895477	0.831841		
8.25	0.911558	0.839906		
8.5	0.923618	0.847585		
8.75	0.934673	0.854895		
9	0.950754	0.861855		
9.25	0.956784	0.86848		
9.5	0.970854	0.874788		
9.75	0.975879	0.880794		
10	0.972864	0.886511		
10.25	0.978894	0.891954		
10.5	0.98191	0.897137		
10.75	0.988945	0.90207		
11	1.001005	0.906767		
11.25	1.001005	0.911239		
11.5	1	0.915496		

Sum of diff.^{2} = sum of the difference^2 between exp. and calc.

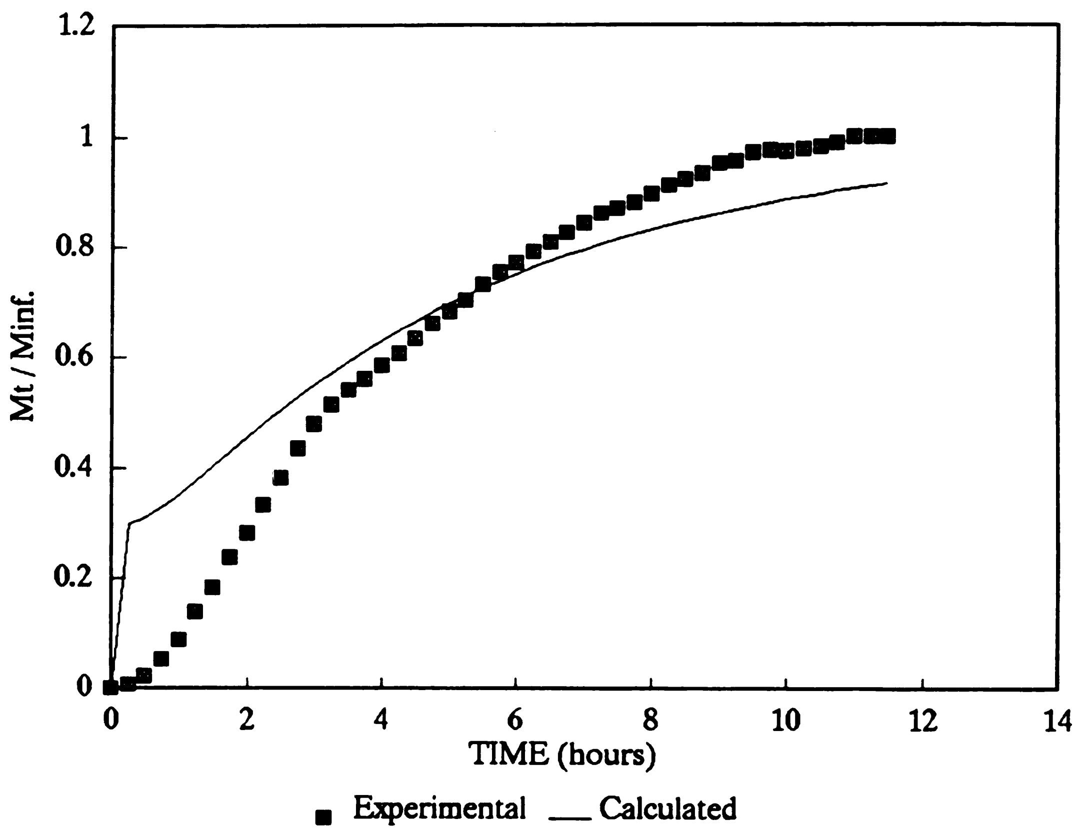

Figure 30. Comparison of experimental and calculated M_t/M_∞ for tablet at 36 - 40% R.H. and 25.0 ° C (SORP C3b)

Table 15. Comparison of experimental and calculated M_t/M_∞ for tablet at 40.75 - 48.80% R.H. and 25.0 °C with determination of diffusion coefficient

Time (hours)	Exp. M_t/M_∞	Calculated M_t/M_∞	$T_{1/2}$ (hours)	Sum of diff.²
0	0	0	3.30	0.08315
1	0.27509	0.326579	3.40	0.081304
2	0.481551	0.39566	3.46	0.080946
3	0.573439	0.468999	**3.47**	**0.080942**
4	0.629289	0.536574	3.48	0.080951
5	0.668916	0.596435	3.49	0.080981
6	0.701795	0.648815	3.50	0.081021
7	0.728643	0.694469		
8	0.753625	0.734208		
9	0.775879	0.768785		
10	0.799569	0.798865	Diffusion	
11	0.819239	0.825032	Coeff. =	
12	0.837904	0.847795	0.002170	
13	0.861307	0.867597	cm²/hour	
14	0.86748	0.884822		
15	0.865757	0.899807		
16	0.854559	0.912842		
17	0.856138	0.924181		
18	0.870065	0.934045		
19	0.884566	0.942626		
20	0.896482	0.95009		
21	0.903087	0.956583		
22	0.909404	0.962232		
23	0.916296	0.967145		
24	0.922757	0.97142		
25	0.927638	0.975138		
26	0.933094	0.978372		
27	0.938406	0.981186		
28	0.943862	0.983634		
29	0.950179	0.985763		
30	0.956927	0.987615		
31	0.964393	0.989227		
32	0.971285	0.990628		
33	0.979469	0.991847		
34	0.986648	0.992908		
35	0.996698	0.993831		
35.5	1	0.994246		

Sum of diff.² = sum of the difference² between exp. and calc.

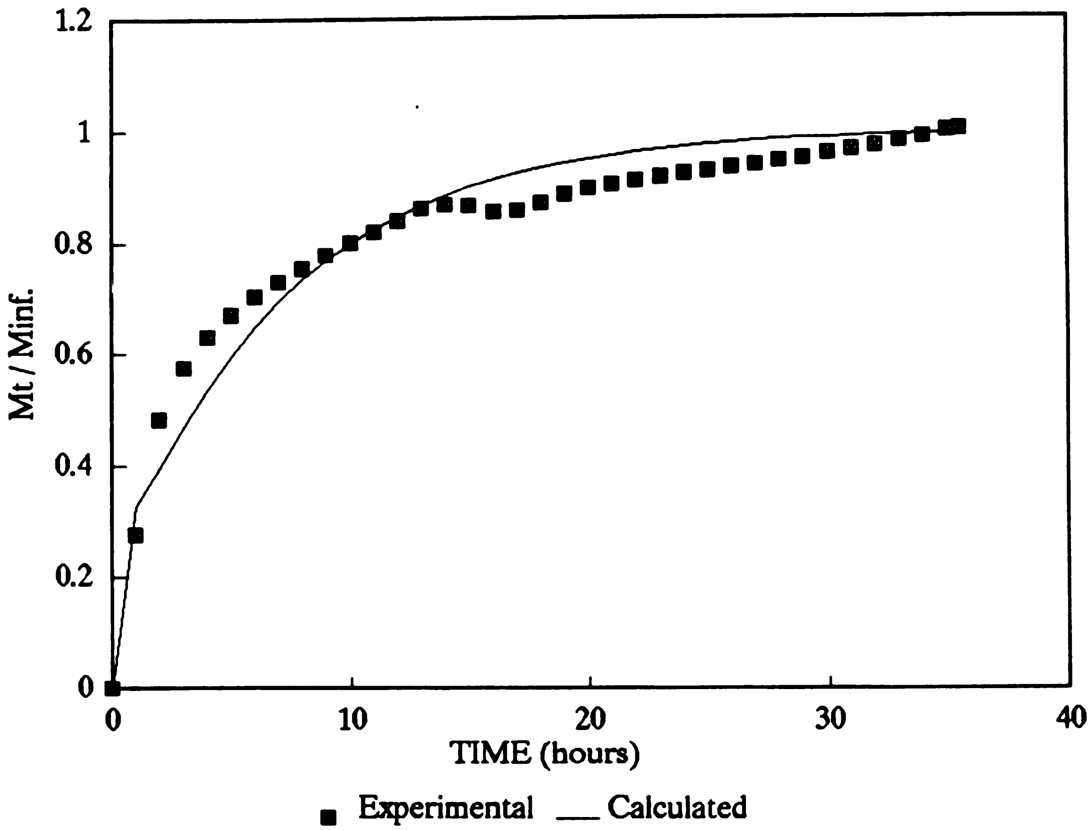

Figure 31. Comparison of experimental and calculated M_t/M_∞ for tablet at 40.75-48.80% R.H. and 25.0 ° C (SORP C5)

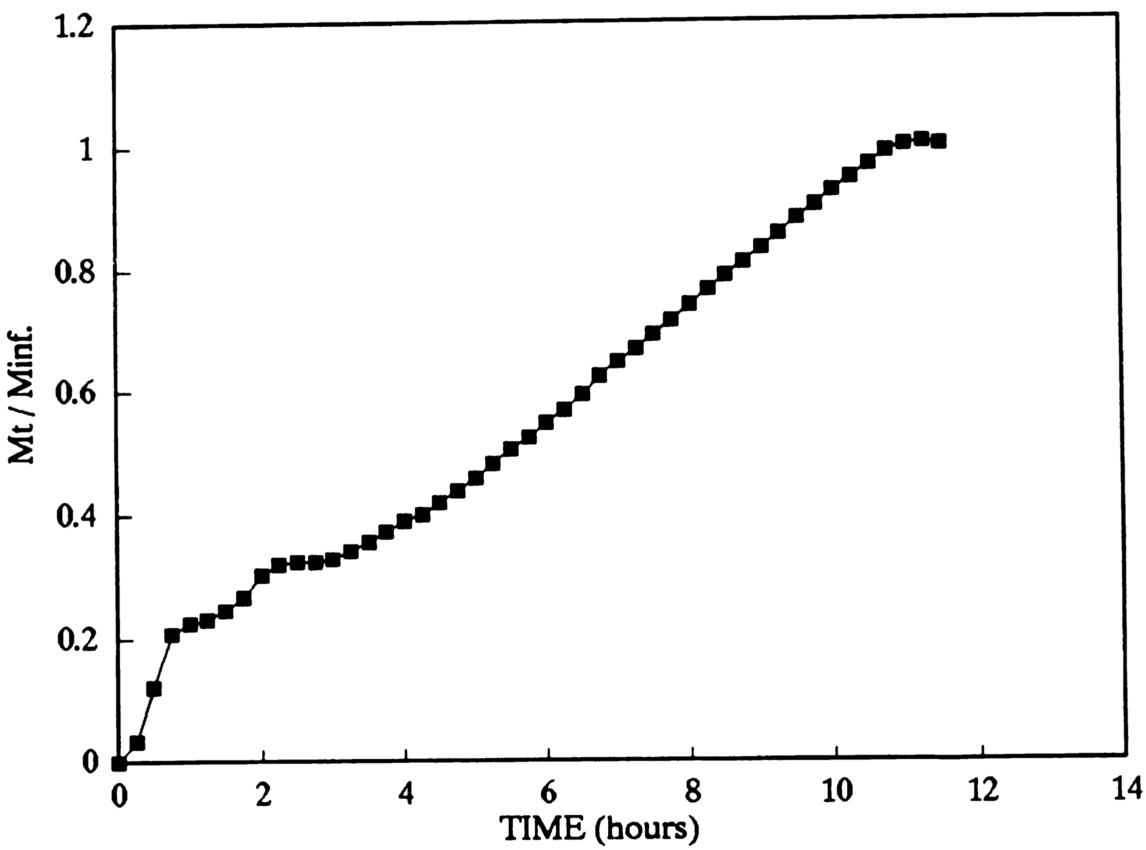

Figure 32. Experimental sorption of tablet at 48.85 - 60.35% R.H., 25.0 ° C (SORP 6C)

Table 16. Comparison of experimental and calculated M_t/M_∞ for tablet at 60.70 - 66% R.H. and 25.0 ° C with determination of diffusion coefficient

Time (hours)	Exp. M_t/M_∞	Calculated M_t/M_∞	$T_{1/2}$ (hours)	Sum of diff.^{2}
0	0	0	1.60	0.164457
0.5	0.00294	0.32929	1.64	0.16293
1	0.191102	0.402445	1.65	0.16278
1.5	0.407291	0.478689	**1.66**	**0.162713**
2	0.542728	0.548098	1.67	0.162736
2.5	0.633281	0.609038	1.68	0.162847
3	0.696394	0.661967	1.70	0.16333
3.5	0.742062	0.707786		
4	0.776362	0.74741		
4.5	0.804194	0.781665		
5	0.828499	0.811275	Diffusion	
5.5	0.849667	0.83687	Coeff. =	
6	0.868091	0.858994	0.004536	
6.5	0.884555	0.878117	cm^2/hour	
7	0.899647	0.894647		
7.5	0.912191	0.908935		
8	0.924735	0.921286		
8.5	0.935711	0.931961		
9	0.945708	0.941189		
9.5	0.957076	0.949165		
10	0.966484	0.956059		
10.5	0.97452	0.962018		
11	0.982556	0.96717		
11.5	0.988436	0.971622		
12	0.989808	0.975471		
12.5	0.988044	0.978797		
13	0.988044	0.981673		
13.5	0.990004	0.984158		
14	0.996472	0.986307		
14.5	1	0.988164		

Sum of diff.^{2} = sum of the difference^2 between exp. and calc.

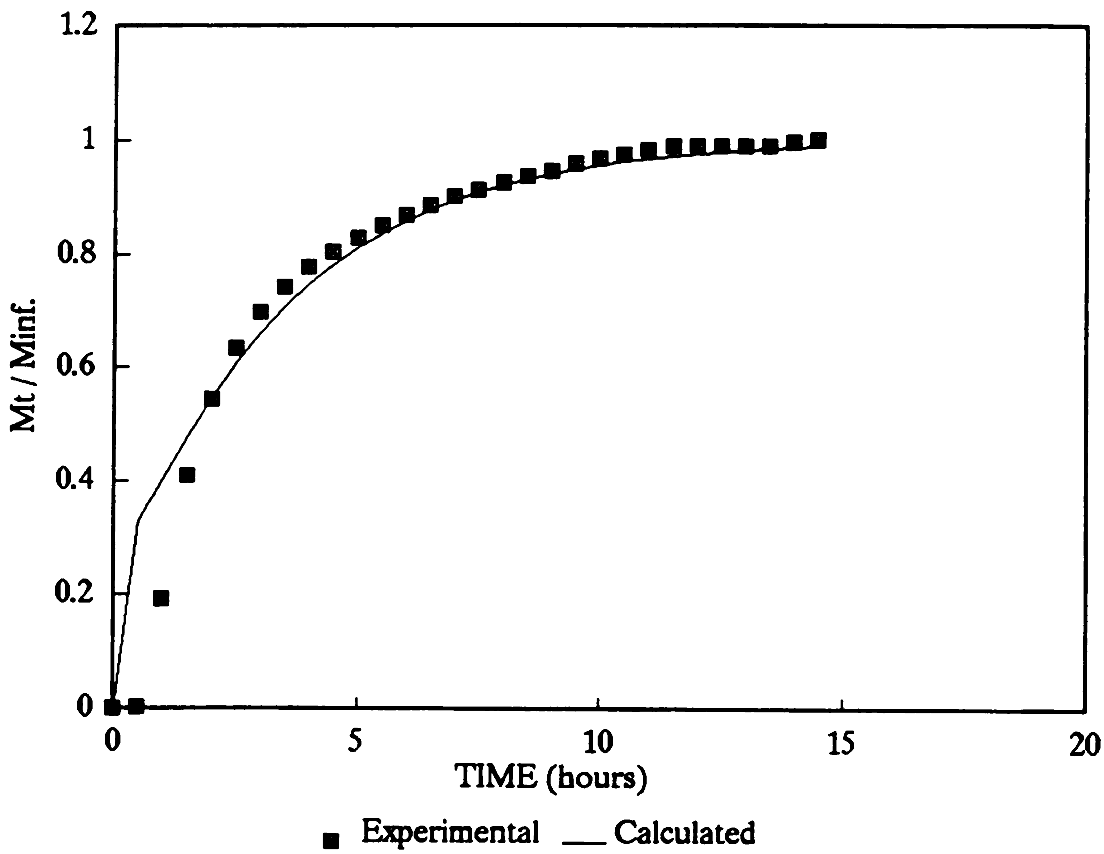

Figure 33. Comparison of experimental and calculated M_t/M_∞ for tablet at 60.70 - 66% R.H. and 25.0 ° C (SORP 7Ca)

Table 17. Comparison of experimental and calculated M_t/M_∞ for tablet at 66 - 73.40% R.H. and 25.0 °C with determination of diffusion coefficient

Time (hours)	Exp. M_t/M_∞	Calculated M_t/M_∞	$T_{1/2}$ (hours)	Sum of diff.^{2}
0	0	0	1.27	0.2142
0.25	0.003256	0.309764	1.28	0.213818
0.5	0.092716	0.34859	1.29	0.213665
0.75	0.224507	0.397027	1.30	0.213742
1	0.341902	0.446755	1.36	0.218822
1.25	0.435476	0.494451	1.40	0.226393
1.5	0.511397	0.538918	1.43	0.234163
1.75	0.572408	0.579853	1.46	0.243604
2	0.622451	0.617315		
2.25	0.665124	0.651507		
2.5	0.701971	0.682674		
2.75	0.732648	0.711067	Diffusion	
3	0.75904	0.736924	Coeff. =	
3.25	0.782519	0.76047	0.005837	
3.5	0.802742	0.78191	cm^2/hour	
3.75	0.81988	0.801431		
4	0.836675	0.819205		
4.25	0.850386	0.835388		
4.5	0.864096	0.850122		
4.75	0.876435	0.863538		
5	0.887746	0.875753		
5.25	0.898543	0.886874		
5.5	0.907798	0.897		
5.75	0.917224	0.90622		
6	0.924764	0.914614		
6.25	0.931962	0.922257		
6.5	0.938646	0.929216		
6.75	0.944987	0.935552		
7	0.951157	0.941321		
7.25	0.956641	0.946573		
7.5	0.962639	0.951355		
7.75	0.967952	0.95571		
8	0.973093	0.959674		
8.25	0.978406	0.963284		
8.5	0.982862	0.96657		
8.75	0.987318	0.969563		
9	0.991945	0.972287		
9.25	0.995716	0.974768		
9.5	0.998972	0.977026		
9.75	1.001371	0.979083		
10	1.002742	0.980955		
10.25	0.991602	0.98266		
10.5	1.002913	0.984212		
10.75	1.002057	0.985625		
11	1	0.986912		

Sum of diff.^{2} = sum of the difference^2 between exp. and calc.

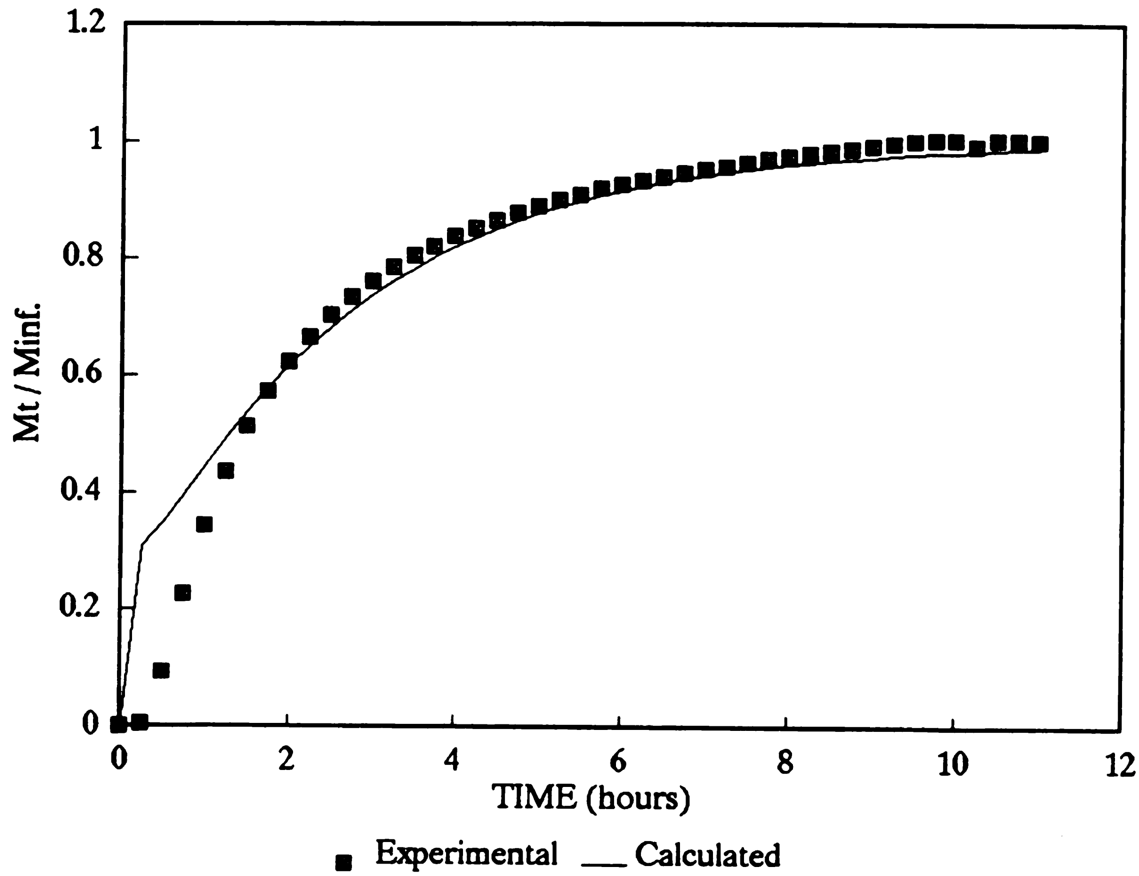

Figure 34. Comparison of experimental and calculated M_t/M_∞ for tablet at 66 - 73.40% R.H. and 25.0 °C (SORP 7Cb)

Table 18. Comparison of experimental and calculated M_t/M_∞ for tablet at 72.25 - 77.75% R.H. and 25.0 °C with determination of diffusion coefficient

Time (hours)	Exp. M_t/M_∞	Calculated M_t/M_∞	$T_{1/2}$ (hours)	Sum of diff.^{2}
0	0	0	1.60	0.051542
0.5	0.126425	0.329647	1.64	0.050668
1	0.332308	0.403324	**1.65**	**0.050656**
1.5	0.47819	0.479935	1.66	0.050726
2	0.569321	0.549571	1.68	0.051105
2.5	0.637466	0.610642	1.70	0.051804
3	0.691493	0.663634	1.72	0.052799
3.5	0.733032	0.709468		
4	0.768597	0.749071		
4.5	0.800271	0.783279		
5	0.823077	0.812825	Diffusion	
5.5	0.842896	0.838344	Coeff. =	
6	0.85991	0.860383	0.004564	
6.5	0.874299	0.879417	cm^2/hour	
7	0.886787	0.895857		
7.5	0.897738	0.910055		
8	0.907692	0.922318		
8.5	0.920271	0.932908		
9	0.93276	0.942055		
9.5	0.942443	0.949955		
10	0.949955	0.956778		
10.5	0.95629	0.962671		
11	0.9619	0.96776		
11.5	0.967149	0.972155		
12	0.971222	0.975952		
12.5	0.975837	0.97923		
13	0.979457	0.982062		
13.5	0.982624	0.984507		
14	0.985068	0.98662		
14.5	0.987692	0.988444		
15	0.990407	0.990019		
15.5	0.992489	0.99138		
16	0.994842	0.992555		
16.5	0.997014	0.99357		
17	0.999548	0.994447		
17.5	1.001448	0.995204		
17.75	1	0.995543		

Sum of diff.^{2} = sum of the difference^2 between exp. and calc.

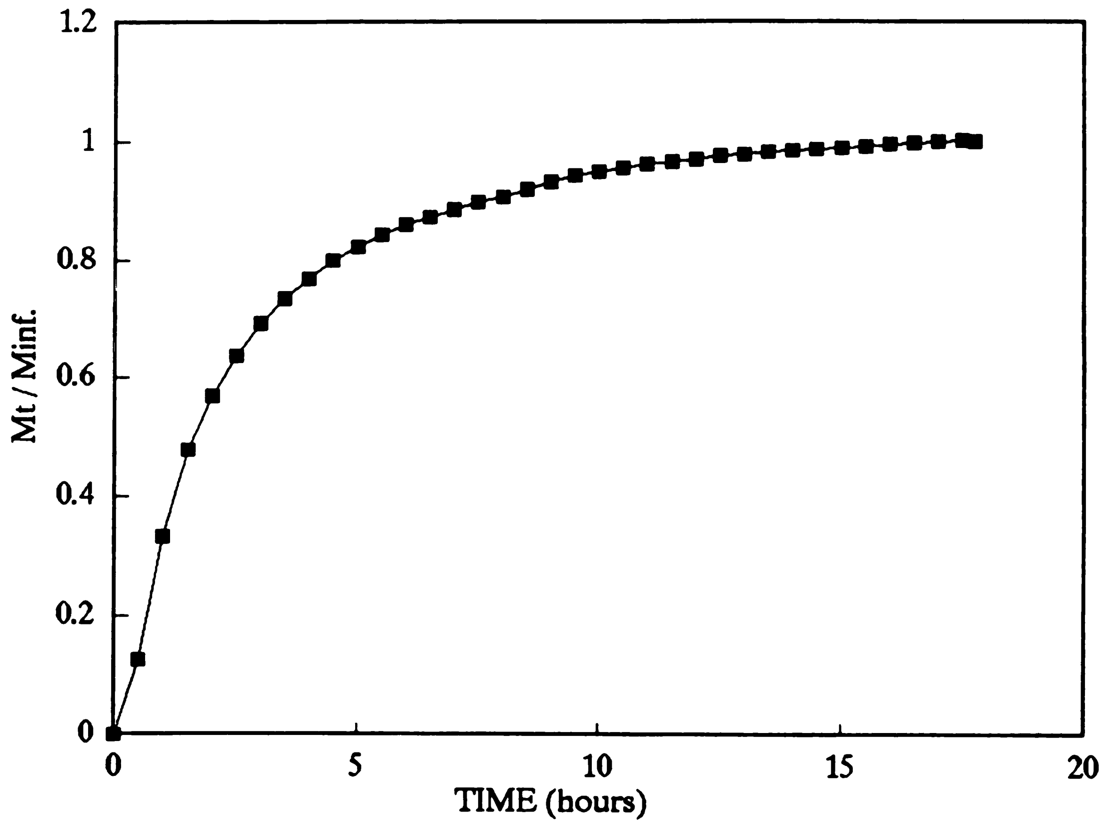

Figure 35. Experimental sorption of tablet at 72.25 - 77.75% R.H., 25.0 ° C (SORP C8)

Table 19. Comparison of experimental and calculated M_t/M_∞ for tablet at 77.90 - 82.45% R.H. and 25.0 °C with determination of diffusion coefficient

Time (hours)	Exp. M_t/M_∞	Calculated M_t/M_∞	$T_{1/2}$ (hours)	Sum of diff.^{2}
0	0	0	1.25	0.074536
0.5	0.191391	0.347156	1.30	0.0726
1	0.337666	0.443662	**1.31**	**0.072598**
1.5	0.453808	0.534866	1.32	0.072723
2	0.557202	0.61278	1.35	0.073829
2.5	0.645778	0.677956	1.40	0.078014
3	0.720778	0.732221	1.45	0.084958
3.5	0.782368	0.777354	1.50	0.094519
4	0.831871	0.814882		
4.5	0.871109	0.846085		
5	0.90505	0.872028		
5.5	0.932781	0.893599	Diffusion	
6	0.953808	0.911533	Coeff. =	
6.5	0.969619	0.926445	0.005748	
7	0.981043	0.938843	cm^2/hour	
7.5	0.991142	0.949152		
8	0.999338	0.957723		
8.5	1.004636	0.964849		
9	1.008692	0.970774		
9.5	1.012169	0.9757		
10	1.015563	0.979796		
10.5	1.019123	0.983201		
11	1.021689	0.986033		
11.5	1.023179	0.988387		
12	1.024338	0.990345		
12.5	1.022599	0.991972		
13	1.020033	0.993325		
13.5	1.017881	0.99445		
14	1.015811	0.995386		
14.5	1.013162	0.996164		
15	1.009272	0.99681		
15.5	1.007036	0.997348		
16	1.004884	0.997795		
16.5	1.00207	0.998167		
16.75	1	0.998328		

Sum of diff.^{2} = sum of the difference^2 between exp. and calc.

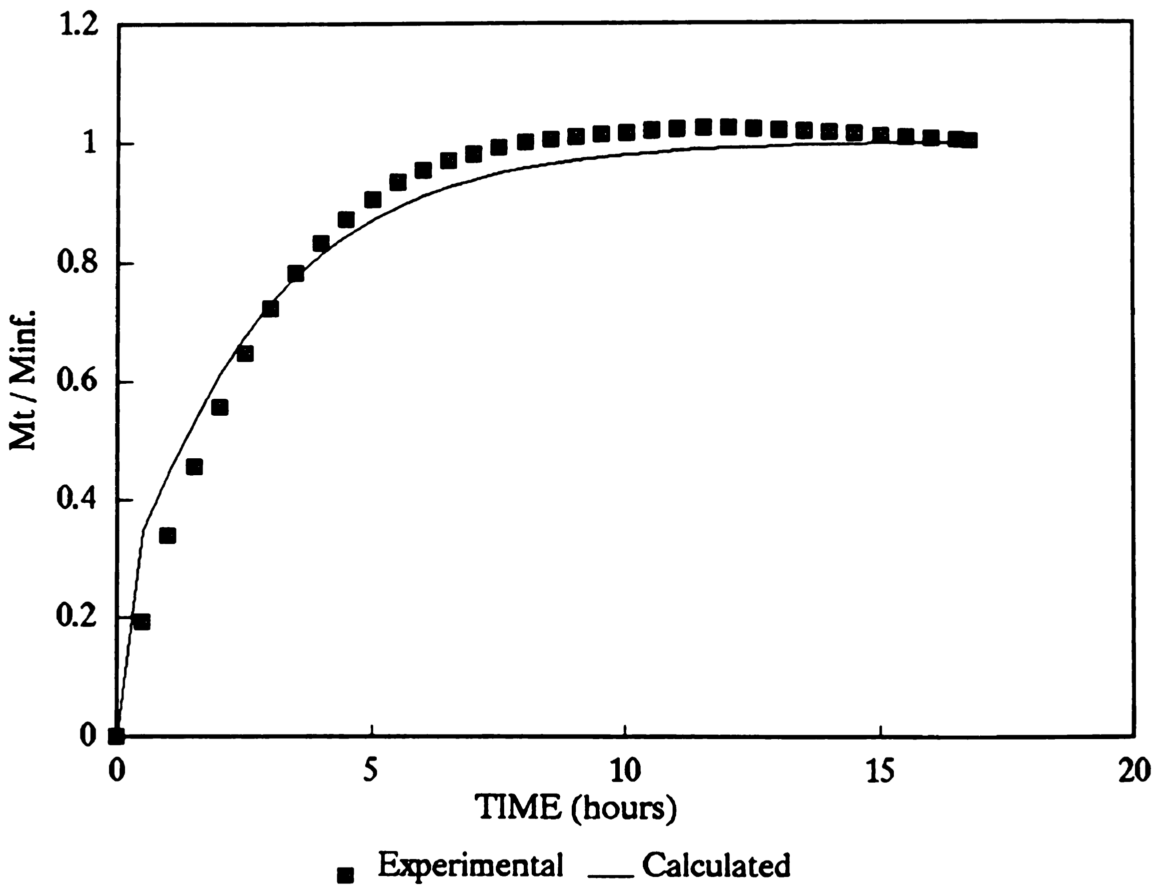

Figure 36. Comparison of experimental and calculated M_t/M_∞ for tablet at 77.90-82.45% R.H. and 25.0 °C (SORP C9)

Table 20. Comparison of experimental and calculated M_t/M_∞ for tablet at 82.05 - 87.30% R.H. and 25.0 $^\circ$C with determination of diffusion coefficient

Time (hours)	Exp. M_t/M_∞	Calculated M_t/M_∞	$T_{1/2}$ (hours)	Sum of diff.^{2}
0	0	0	2.08	0.038614
1	0.215121	0.37013	2.09	0.038574
2	0.439014	0.490327	**2.10**	**0.038571**
3	0.577833	0.593975	2.11	0.038603
4	0.670774	0.677335	2.15	0.039101
5	0.741994	0.74368	2.20	0.040502
6	0.799151	0.796395	2.25	0.042795
7	0.845725	0.838271	2.30	0.045849
8	0.883111	0.871534		
9	0.913464	0.897956		
10	0.938179	0.918944		
11	0.959343	0.935615	Diffusion	
12	0.975494	0.948857	Coeff. =	
13	0.989	0.959376	0.003585	
14	0.999582	0.967731	cm^2/hour	
15	1.004107	0.974368		
16	1.006892	0.97964		
17	1.007449	0.983827		
18	1.007519	0.987153		
19	1.007937	0.989796		
20	1.009816	0.991894		
21	1.012531	0.993561		
22	1.013854	0.994886		
23	1.015664	0.995938		
24	1.020955	0.996773		
25	1.024854	0.997437		
26	1.02374	0.997964		
27	1.021791	0.998383		
28	1.01817	0.998715		
29	1.013436	0.99898		
30	1.008911	0.999189		
31	1.005569	0.999356		
32	1.001184	0.999489		
32.25	1	0.999517		

Sum of diff.^{2} = sum of the difference^2 between exp. and calc.

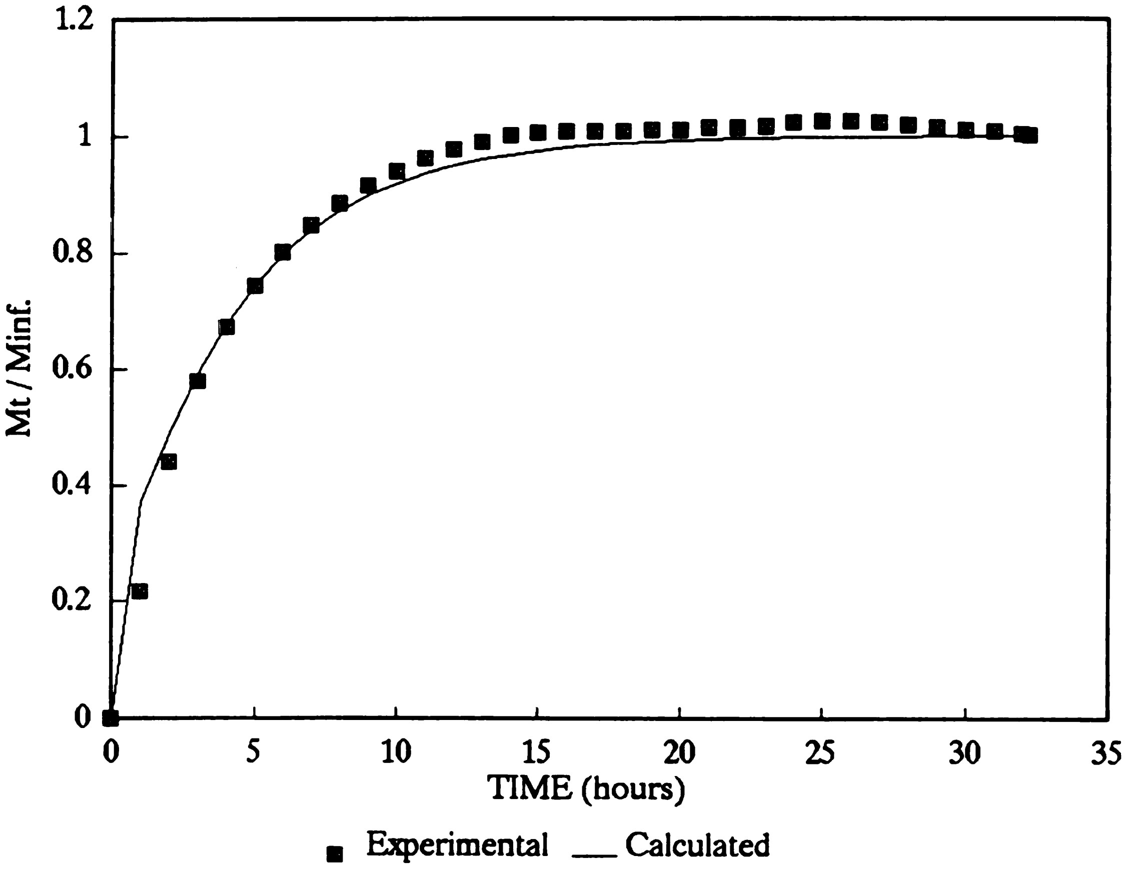

Figure 37. Comparison of experimental and calculated M_t/M_∞ for tablet at 82.05-87.30% R.H. and 25.0 °C (SORP 10)

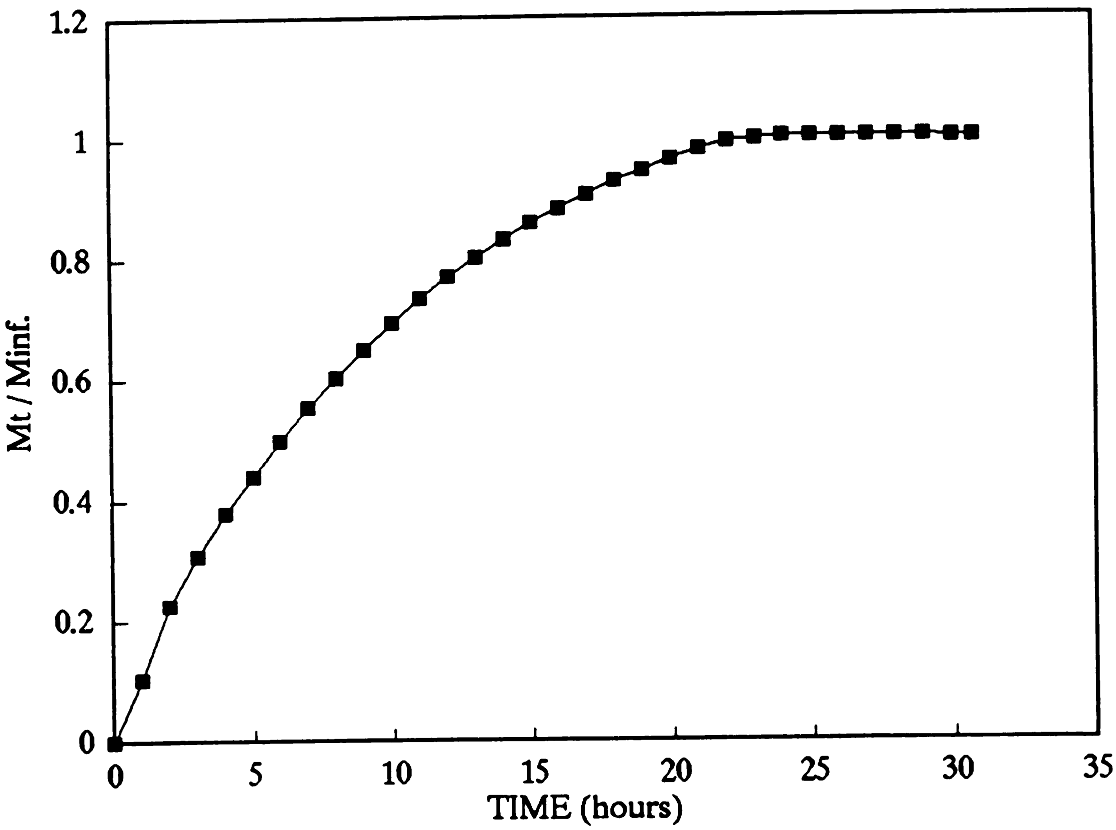

Figure 38. Experimental sorption of tablet at 86.70 - 91.70% R.H., 25.0 ° C (SORP 13)

APPENDIX C

APPENDIX C

Sorption Experiment of PVC Film

Table 21. Summary of sorption experiments of PVC film at 25.0 $^{\circ}$ C

Test Number	Experimental Test	Relative Humidity Range (%)
1	SORP P1	0 - 26.90
2	SORP P2	26.65 - 43.50
3	SORP P3	43.50 - 58.20
4	SORP P4	58.20 - 77

Table 22. Moisture sorption isotherm data for PVC film at 25.0 $^{\circ}$ C

A_w	Absolute Film Weight (mg)	Film Weight Change (mg)	EMC (g H_2O/ 100 g dry product)	Calc. EMC (g H_2O/ 100 g dry product)
0	193.9691	0	0	0
0.269	194.0393	0.0702	0.036	0.046
0.435	194.1173	0.1482	0.076	0.074
0.582	194.1622	0.1931	0.1	0.099
0.77	194.2264	0.2573	0.133	0.131

A_w = Water activity
EMC = Equilibrium Moisture Content
Calc. = Calculated

Table 23. Comparison of experimental and calculated M_t/M_∞ for PVC film at 0 - 26.90% R.H. and 25.0 ° C with determination of diffusion coefficient

Time (hours)	Exp. M_t/M_∞	Calculated M_t/M_∞	$T_{1/2}$ (hours)	Sum of diff.²
0	0	0	0.74	0.040469
0.5	0.373219	0.39354	0.80	0.03044
1	0.586895	0.532911	0.82	0.029135
1.5	0.696581	0.644594	0.84	0.027906
2	0.762108	0.729935	0.86	0.027173
2.5	0.806268	0.794814	0.87	0.026994
3	0.847578	0.844109	**0.88**	**0.026993**
3.5	0.873219	0.881561	0.89	0.02709
4	0.894587	0.910016	0.90	0.02729
4.5	0.908832	0.931635		
5	0.911681	0.948059		
5.5	0.924501	0.960538		
6	0.930199	0.970019	Diffusion	
6.5	0.935897	0.977222	Coeff. =	
7	0.935897	0.982694	2.01 E -05	
7.5	0.950142	0.986852	cm²/hour	
8	0.951567	0.990011		
8.5	0.954416	0.992411		
9	0.958689	0.994234		
9.5	0.960114	0.995619		
10	0.962963	0.996672		
10.5	0.972934	0.997471		
11	0.974359	0.998079		
11.5	0.977208	0.99854		
12	0.981481	0.998891		
12.5	0.987179	0.999157		
13	0.992877	0.99936		
13.5	0.994302	0.999514		
14	0.998575	0.999631		
14.5	0.994302	0.999719		
15	1.002849	0.999787		
15.5	1.005698	0.999838		
16	1.008547	0.999877		
16.5	1.012821	0.999906		
17	1.014245	0.999929		
17.5	1.01567	0.999946		
18	1.004274	0.999959		
18.5	1	0.999969		

Sum of diff.² = sum of the difference² between exp. and calc.

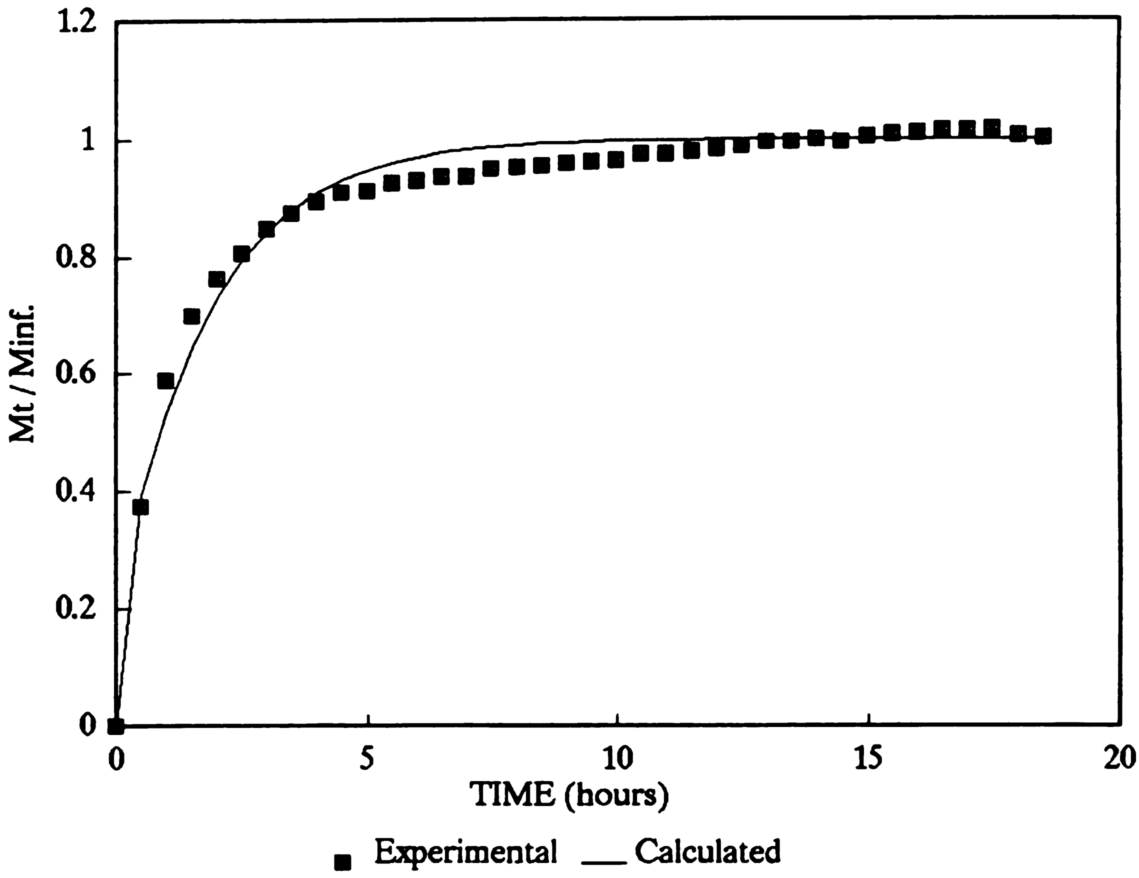

Figure 39. Comparison of experimental and calculated M_t/M_∞ for PVC film at 0 - 26.90% R.H. and 25.0 ° C (SORP P1)

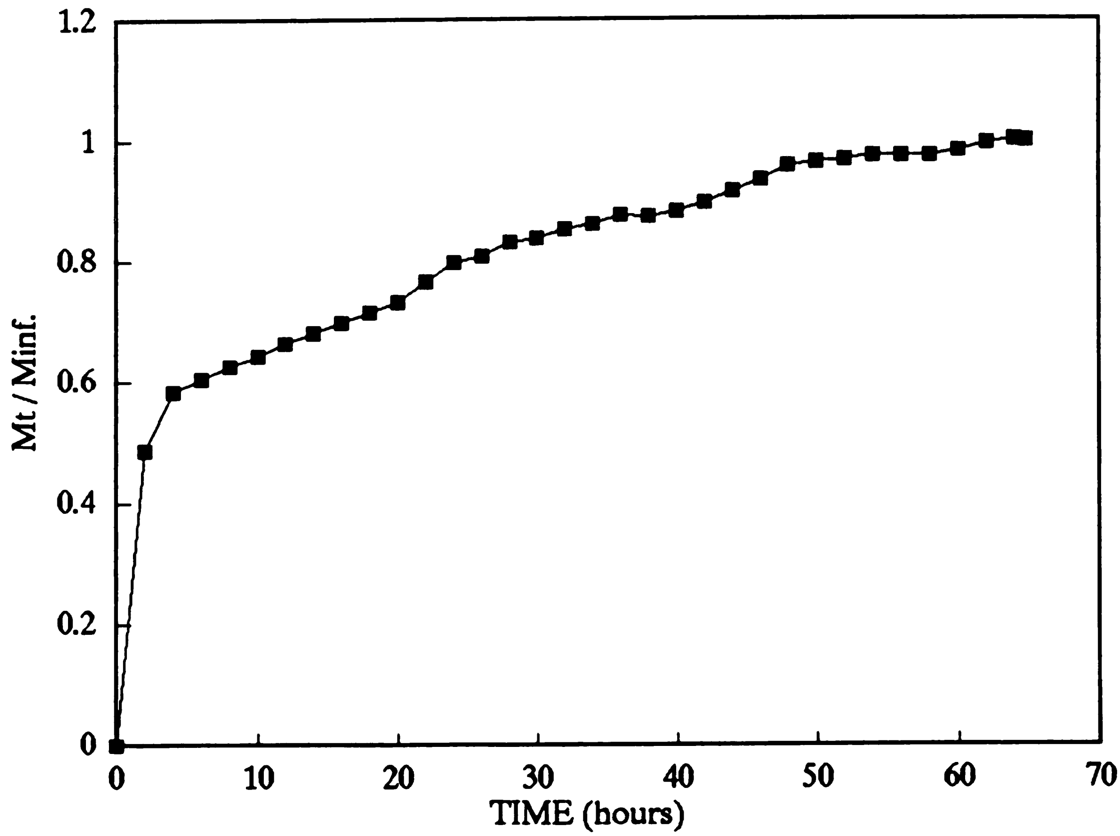

Figure 40. Experimental sorption of PVC film at 26.65-43.50% R.H., 25.0 ° C (SORP P2)

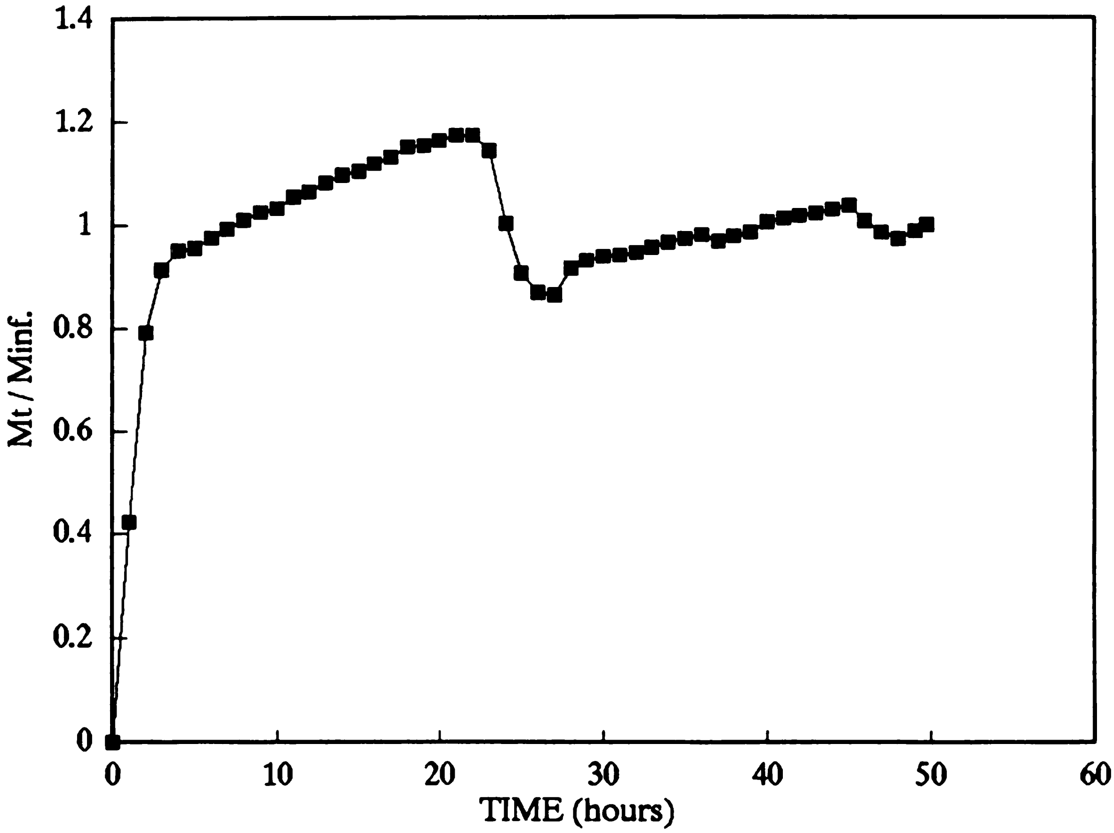

Figure 41. Experimental sorption of PVC film at 43.50-58.20% R.H., 25.0 ° C (SORP P3)

Table 24. Comparison of experimental and calculated M_t/M_∞ for PVC film at 58.20 - 77% R.H. and 25.0 °C with determination of diffusion coefficient

Time (hours)	Exp. M_t/M_∞	Calculated M_t/M_∞	$T_{1/2}$ (hours)	Sum of diff.^{2}
0	0	0	1.05	0.048983
0.5	0.203288	0.365588	1.06	0.048705
1	0.439462	0.48154	1.07	0.048296
1.5	0.596413	0.583157	1.08	0.048169
2	0.699552	0.665774	1.09	0.048075
2.5	0.769806	0.73214	1.10	0.048112
3	0.814649	0.785346	1.14	0.049606
3.5	0.849028	0.827985		
4	0.877429	0.862155		
4.5	0.896861	0.889537		
5	0.910314	0.91148		
5.5	0.920777	0.929064		
6	0.932735	0.943155		
6.5	0.93722	0.954447		
7	0.944694	0.963496		
7.5	0.947683	0.970747		
8	0.949178	0.976558	Diffusion Coeff. = 1.62 E -05 cm^2/hour	
8.5	0.950673	0.981215		
9	0.964126	0.984946		
9.5	0.971599	0.987937		
10	0.980568	0.990333		
10.5	0.979073	0.992253		
11	0.980568	0.993792		
11.5	0.989537	0.995025		
12	0.995516	0.996013		
12.5	1.00299	0.996805		
13	1.008969	0.99744		
13.5	1.017937	0.997949		
14	1.025411	0.998356		
14.5	1.029895	0.998683		
15	1.035874	0.998944		
15.5	1.037369	0.999154		
16	1.037369	0.999322		
16.5	1.037369	0.999457		
17	1.037369	0.999565		
17.5	1.028401	0.999651		
18	1.019432	0.99972		
18.5	1.010463	0.999776		
19	1.010463	0.99982		
19.5	1.007474	0.999856		
20	1.00299	0.999885		
20.5	1.007474	0.999908		
21	1.004484	0.999926		
21.5	1.001495	0.999941		
22	1.008969	0.999952		
22.5	1.014948	0.999962		
23	1.010463	0.999969		
23.5	1	0.999976		

Sum of diff.^{2} = sum of the difference^2 between exp. and calc.

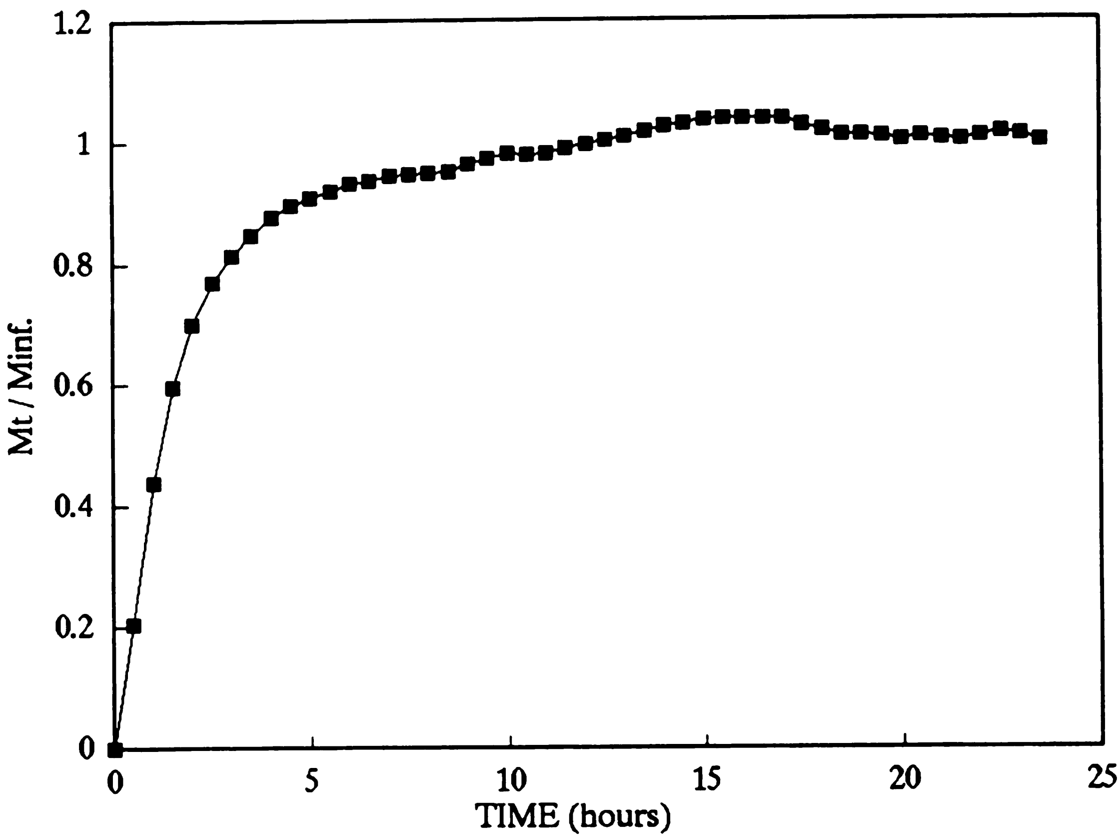

Figure 42. Experimental sorption of PVC film at 58.20-77% R.H., 25.0 ° C (SORP P4)

APPENDIX D

APPENDIX D

Sorption Experiment of Aclar Film

Table 25. Summary of sorption experiments of Aclar film at 25.0 °C

Test Number	Experimental Test	Relative Humidity Range (%)
1	SORP L2	0 - 27.35
2	SORP L4	27.35 - 43.50
3	SORP L6	43.50 - 58
4	SORP L7	58 - 74.45

Table 26. Moisture sorption isotherm data for Aclar film at 25.0 °C

A_w	Absolute Film Weight (mg)	Film Weight Change (mg)	EMC (g H_2O/ 100 g dry product)	Calc. EMC (g H_2O/ 100 g dry product)
0	50.7371	0	0	0.003
0.274	50.7649	0.0278	0.055	0.054
0.435	50.7797	0.0426	0.084	0.083
0.58	50.7983	0.0612	0.121	0.11
0.745	50.8034	0.0663	0.131	0.14

A_w = Water activity
EMC = Equilibrium Moisture Content
Calc. = Calculated

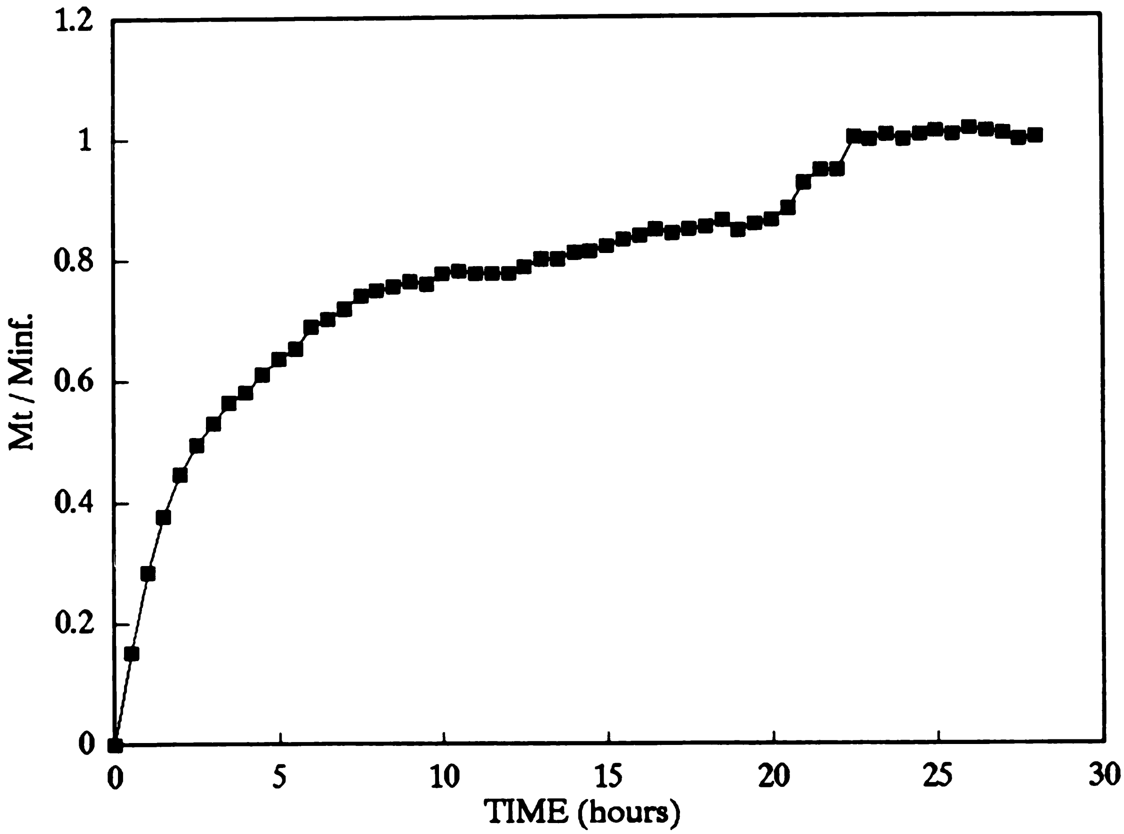

Figure 43. Experimental sorption of Aclar film at 0 - 27.35% R.H., 25.0 °C (SORP L2)

Table 27. Comparison of experimental and calculated M_t/M_∞ for Aclar film at 27.35 - 43.50% R.H. and 25.0 °C with determination of diffusion coefficient

Time (hours)	Exp. M_t/M_∞	Calculated M_t/M_∞	$T_{1/2}$ (hours)	Sum of diff.²
0	0	0	0.50	0.089474
0.25	0.422857	0.348129	0.52	0.077926
0.5	0.508571	0.445762	0.55	0.064347
0.75	0.594286	0.53762	0.58	0.053588
1	0.657143	0.615863	0.61	0.048002
1.25	0.737143	0.681165	0.64	0.045094
1.5	0.754286	0.735422	**0.65**	**0.044979**
1.75	0.777143	0.780456	0.66	0.045197
2	0.811429	0.817827	0.67	0.045868
2.25	0.828571	0.848837		
2.5	0.822857	0.874568		
2.75	0.84	0.895919		
3	0.845714	0.913636	Diffusion	
3.25	0.868571	0.928337	Coeff. =	
3.5	0.891429	0.940536	1.21 E -06	
3.75	0.908571	0.950658	cm²/hour	
4	0.931429	0.959057		
4.25	0.942857	0.966026		
4.5	0.954286	0.971809		
4.75	0.965714	0.976608		
5	0.988571	0.98059		
5.25	1.011429	0.983894		
5.5	1.011429	0.986636		
5.75	1.022857	0.98891		
6	1.028571	0.990798		
6.25	1.022857	0.992365		
6.5	1.011429	0.993664		
6.75	0.994286	0.994743		
7	1	0.995638		
7.25	1.017143	0.99638		
7.5	1.017143	0.996996		
7.75	1.017143	0.997508		
8	1.011429	0.997932		
8.25	1	0.998284		

Sum of diff.² = sum of the difference² between exp. and calc.

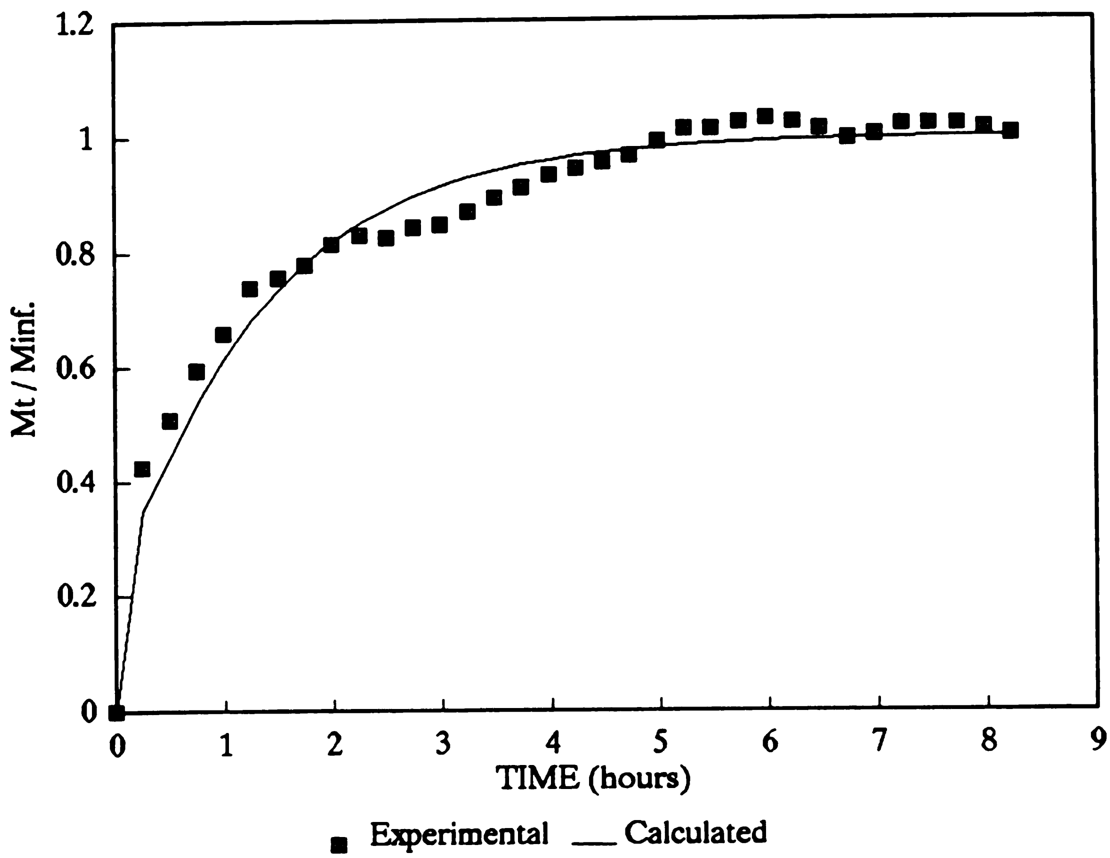

Figure 44. Comparison of experimental and calculated M_t/M_∞ for Aclar film at 27.35-43.50% R.H., 25.0 °C (SORP L4)

Table 28. Comparison of experimental and calculated M_t/M_∞ for Aclar film at 43.50 - 58% R.H. and 25.0 °C with determination of diffusion coefficient

Time (hours)	Exp. M_t/M_∞	Calculated M_t/M_∞	$T_{1/2}$ (hours)	Sum of diff.^{2}
0	0	0	0.25	0.02068
0.25	0.485577	0.454602	0.27	0.010792
0.5	0.644231	0.628646	0.30	0.004109
0.75	0.735577	0.748548	**0.31**	**0.00372**
1	0.826923	0.829778	0.32	0.00415
1.25	0.860577	0.884768	0.33	0.005298
1.5	0.903846	0.921994		
1.75	0.932692	0.947194		
2	0.971154	0.964253		
2.25	0.990385	0.975801	Diffusion	
2.5	0.995192	0.983618	Coeff. =	
2.75	1.004808	0.98891	2.53 E -06	
3	1.009615	0.992493	cm^2/hour	
3.25	1.004808	0.994918		
3.5	1.009615	0.99656		
3.75	1	0.997671		
4	1	0.998423		

Sum of diff.^{2} = sum of the difference^2 between exp. and calc.

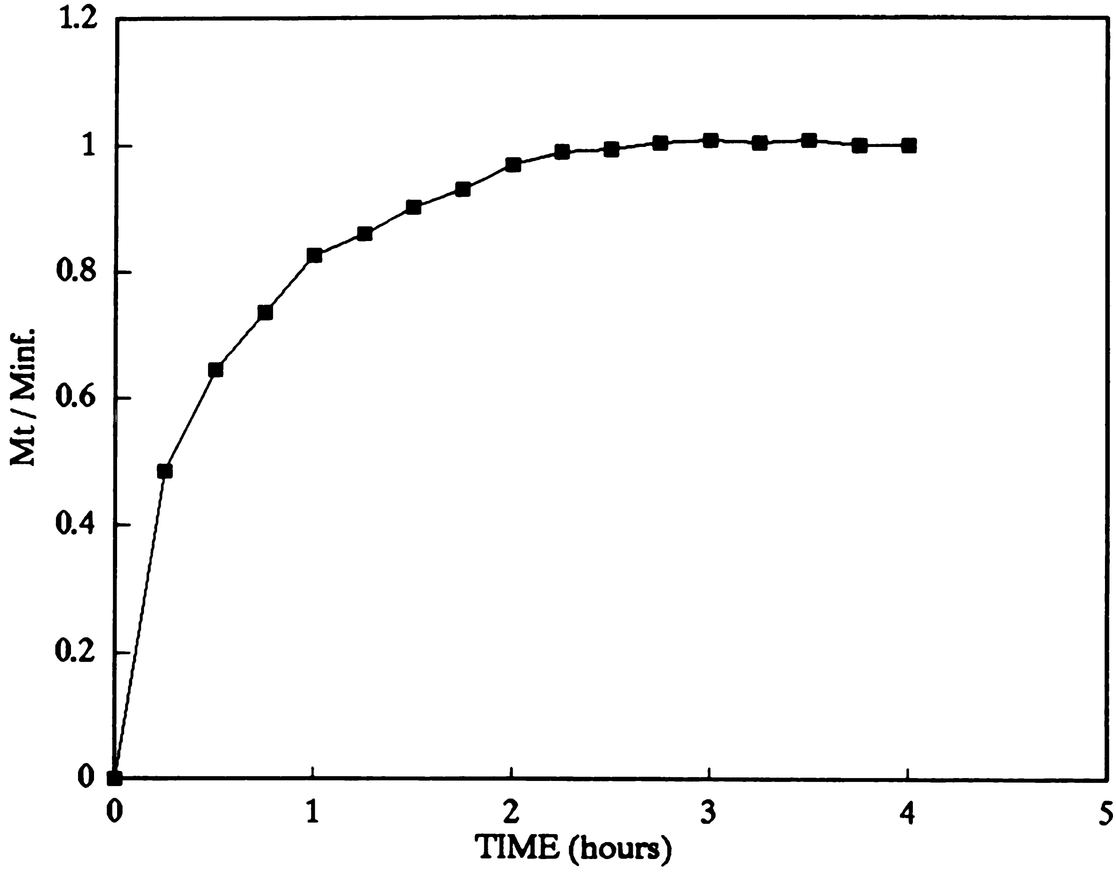

Figure 45. Experimental sorption of Aclar film at 43.50 - 58% R.H., 25.0 ° C (SORP L6)

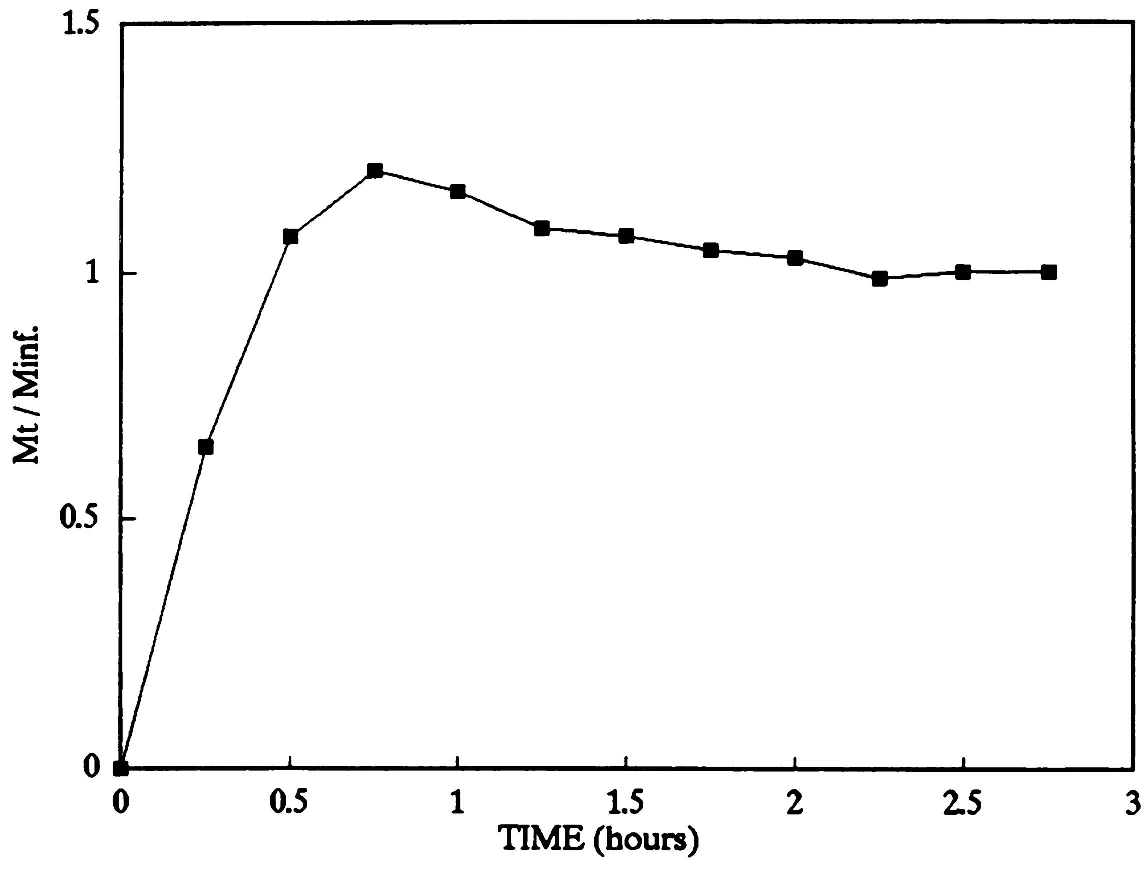

Figure 46. Experimental sorption of Aclar film at 58 - 74.45% R.H., 25.0 ° C (SORP L7)

APPENDIX E

APPENDIX E

Water Vapor Transmission Rate and Permeability of Materials

Table 29. WVTR and Permeability of blister materials at 37.78 ° C and 85% R.H. (Dish Method)

Pkg. Mat'l.	Weight Gain (grams) 7 days	21 days	35 days	WVTR	Perm.
Aclar 1	0.0426	0.086	0.1099	0.5163	0.0196
Aclar 2	0.0097	0.0264	0.0471	0.2213	0.00838
Aclar 3	0.0063	0.0271	0.0457	0.2147	0.00813
PVC 1	0.0554	0.1144	0.1622	0.762	0.135
PVC 2	0.0496	0.1114	0.165	0.7751	0.138
PVC 3	0.0536	0.1088	0.1562	0.7338	0.13
PVC/Aclar1	0.006	0.0196	0.0354	0.1663	0.0358
PVC/Aclar2	0.005	0.0156	0.0334	0.1569	0.0338
PVC/Aclar3	0.0655	0.1275	0.1677	0.7878	0.17

WVTR = Water Vapor Transmission Rate (g / m^2 day)

Perm. = Permeability (g mil / m^2 day mmHg)

Area of dish = 0.00608 m^2

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