The Effect of Moisture on Blistering During the Heat-sealing of Paper and Foil Containing Packaging

By: Lee J Murray (Alcan Packaging[1])

ABSTRACT
Limiting the amount of moisture in paper included in impermeable packaging is necessary to prevent internal delamination known as blistering during the heat sealing of packages for articles such as personal care devices, pharmaceutical tablets, denture tablets, etc. The relationship between moisture content and the blistering problem is shown in both lab tests and package leaker rate data from packaging lines. Recommendations for dealing with the problem are made.

BACKGROUND
Packaging containing an outer, heat resistant, printed paper layer and an internal layer of aluminum foil constitute a large segment of packaging because of a favorable cost to performance ratio. These are often referred to as paper-poly-foil-poly structures. Examples of packaging recognizable to most people include:

- Hand towelettes
- Dry food products and drink mixes
- Antacid tablet packages (single unit dose)
- Denture Cleaning Tablets
- Personal Care Device Packaging

A common problem with this kind of packaging is that moist paper will release steam under pressure when rapidly heated to temperatures needed to fabricate packages. The steam expands between the foil and the semi-permeable printed and varnished surface. A commonly seen consequence of this steam pressure is that the paper will separate from the molten polyethylene laminate. The polymer relaxes to a smooth coating on foil and leaves an unbounded region known as a blister. The blister region is has increased susceptibility to damage because the foil and sealant are no longer connected to the higher strength paper component. Problems of leaks and blisters are more likely to take place in summertime and less likely during dry winter months.

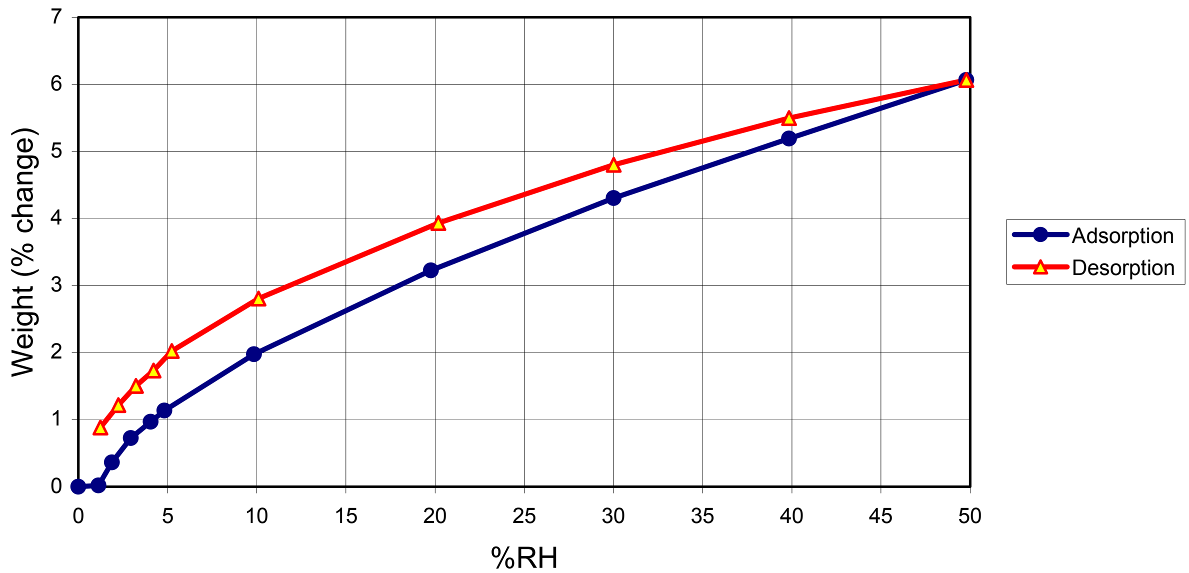
It is well known that paper is hygroscopic and rapidly absorbs moisture when placed in a moist environment. TAPPI standard moisture sorption curves for wood fiber in pulp and paper[2] show a humidity hysteresis with paper being less prone to desorb than absorb moisture. An example is shown on a particular grade of uncoated medical paper[3] (see Figure 1). In this particular case an experiment raised the humidity of a dry paper to 50% RH and then decreased the humidity to a nearly dry state. In the case of coated papers the amount of water would appear to be lower on a weight percent basis.

The paper is supplied with about 3% moisture. If the paper is printed and varnished it is likely that the moisture content may fall as a result of the printing press ovens used to remove solvents or water in the printing process. The paper's moisture content may drop further during extrusion lamination to aluminum foil. The moisture sorption or desorption that takes place after the packaging is manufactured will depend upon the storage conditions and whether the rolls are protected from ambient moisture via protective overwrap.

---

[1] Formerly Pechiney Plastic Packaging
[2] TAPPI Standard Test Method, *Standard conditioning and testing atmospheres for paper, board, pulp handsheets, and related products*, T 402 om-93
[3] Moisture Sorption Isotherm results from a contracted test on bleached board as determined by VTI Corporation of Hialeah, FL

Figure 1
Moisture Sorption Isotherm for an Uncoated Medical Paper



DISCUSSION
Packaging Case History:
In this particular case, the inspection of seal defects was carried out by three methods:

- Light box inspection for fractured foil
- Vacuum inspection under water looking for escaping bubbles
- Inspection for discolored or soiled packages resulting from product leaking from the package.

The bad seals in this case were most often found by discoloration of the packaging from seepage of a fluid out of the package, but sometimes the seals are physically open. Inspections are conducted off the packaging machine where package leaks were not normally found and two other subsequent times when the package leaks show up as the product fluid is able to migrate through channels to the outside of the package. For the time period of August 1 through September 17, a seal defect rate of 0.05% was observed. All of the defects were in four lots of packaging. The worst machine had a seal defect rate of 0.8%. Most of the defects were taking place on one type of machine without a preheat station while other machine types with preheat stations had significantly lower failure rates. Packaging machine operators noted that more leaks were occurring when using the outer 1/2 inch of the problem rolls with less or no problems near the core of the rolls. Furthermore, the leaks appeared to be coming from the outer edges of the two up configuration. Peeling back the paper showed only metal foil with no paper residue on the foil side.

It was suspected that excessive paper moisture was a likely cause of the problem. A validation of that theory was needed as well as a determination of a threshold moisture level and a way to maintain the packaging below that threshold. Samples of packaging were taken down into the roll and the moisture content measured by weight loss after a 16 hour bake in a 70°C oven. The weight loss results are shown in Table I as "percent paper moisture". The formula for converting weight loss to paper moisture level is as follows:

Paper Moisture (%) = 100 × (initial weight – final weight) ÷ (initial weight × .356)
Where 0.356 is the fraction of the packaging that is paper

Table I
Paper Moisture Content in Two Axes for Two Rolls

V12053 - Roll ½ Set 11 Cut 5					V11948 – Roll 5, Set 10, Cut 7				
Inches in from top	Edge 1	Middle	Edge 2	Avg:	Inches in from top	Edge 1	Middle	Edge 2	Avg:
0.00	3.52%	3.84%	3.48%	3.61%	0.00	3.81%	3.99%	3.86%	3.88%
0.13	3.06%	2.99%	3.10%	3.05%	0.13	3.70%	3.24%	4.00%	3.65%
0.25	2.90%	2.94%	3.39%	3.08%	0.25	3.78%	3.53%	3.49%	3.60%
1.50	2.85%	2.75%	3.75%	3.12%	1.50	2.94%	3.08%	3.04%	3.02%
4.00	2.80%	2.65%	3.45%	2.97%	4.00	3.29%	2.80%	2.76%	2.95%
Avg:	3.03%	3.03%	3.43%		Avg:	3.50%	3.33%	3.43%	

Lab Testing:

The paper-poly-foil-poly structures tested is 35.6 % Paper by weight and has the construction:
Varnish and print/ 26# clay coated Paper / LDPE/ Foil / EAA/ LDPE

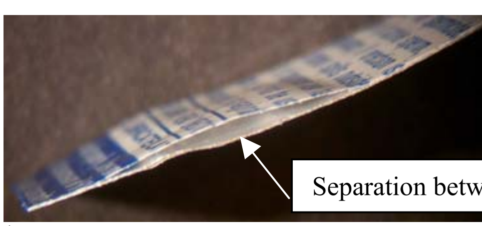
Tests were conducted on packaging material equilibrated to different levels of humidity using environmental chambers of known relative humidity. The moisture content of the total structure was determined using a Mitsubishi CA-100 coulometric Karl Fischer moisture analyzer equipped with a VA-100 vaporizer unit. Dry nitrogen gas is transported over the sample in a heated zone and bubbled into a Karl Fischer solution for titration. In this case the method included the following feature in Table II.

Table II
KF Method Parameters
Delay: 1 min
Min. Titration Time: 3 min
Titration Stop: 0
End Sense: 0.1 (0.1 above background value before start)
VA Select: 1
VA Temp: 150° C
N_2 Flow Rate: 150 ml./min
Purge: 1 min
Pre Heat: 2 min
Cooling: 2 min

Because paper can take up and lose moisture rapidly, the samples were carried between workstations in moisture barrier pouches and stoppered test tubes.

A blistering rating was established for the packaging samples using an eight station Sencorp Model 24 ASG/1 Gradient Thermal Bar Sealer using a dwell time of 1.0 seconds and a bar pressure of 50 psi. Samples of known moisture content were folded over, sealant to sealant, and heat-sealed on this one side heated smooth bar sealer. The heat sealer was cycled several times before each seal to heat the rubber covered bottom bar. Minimums of three seals were made at each temperature over a range of 300 to 400°F. Cross-sections were made into any suspicious looking seal. The seals were inspected under a stereomicroscope with a fiber ring light illumination at ~ 7 X magnification. A dental pick was used to determine if a delamination had occurred in the seal area (see Figure 2). An arbitrary blister rating of 0 to 5 was assigned to each seal with a 5 rating given to a seal with 30 or more percent of the seal area being delaminated. A rating of 0 was given to a seal with no observable delamination. The blister rating by seal temperature and moisture level is plotted in Figure 3. The data was analyzed by a multiple linear regression analysis[4] to predict what seal temperatures could be used with packaging having a specific amount of paper moisture. The regression data was plotted showing the relationship between paper moisture and blistering for the subject structure as shown in Figure 4.

Figure 2
Micrograph of Level 5 Blister in Seal Region
(X-section through Seal Area)



[4]STATGRAPHICS Plus for Windows Version 4.0 Professional System by Manugistics, Inc.

Figure 3
Blistering as a Function of Seal Temperature and Paper Moisture

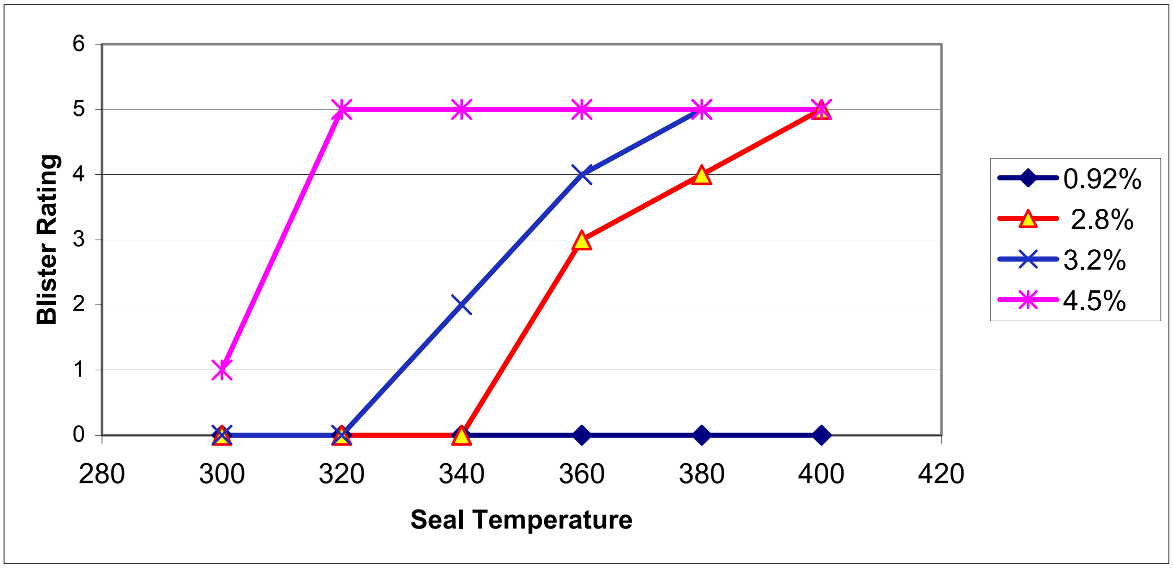
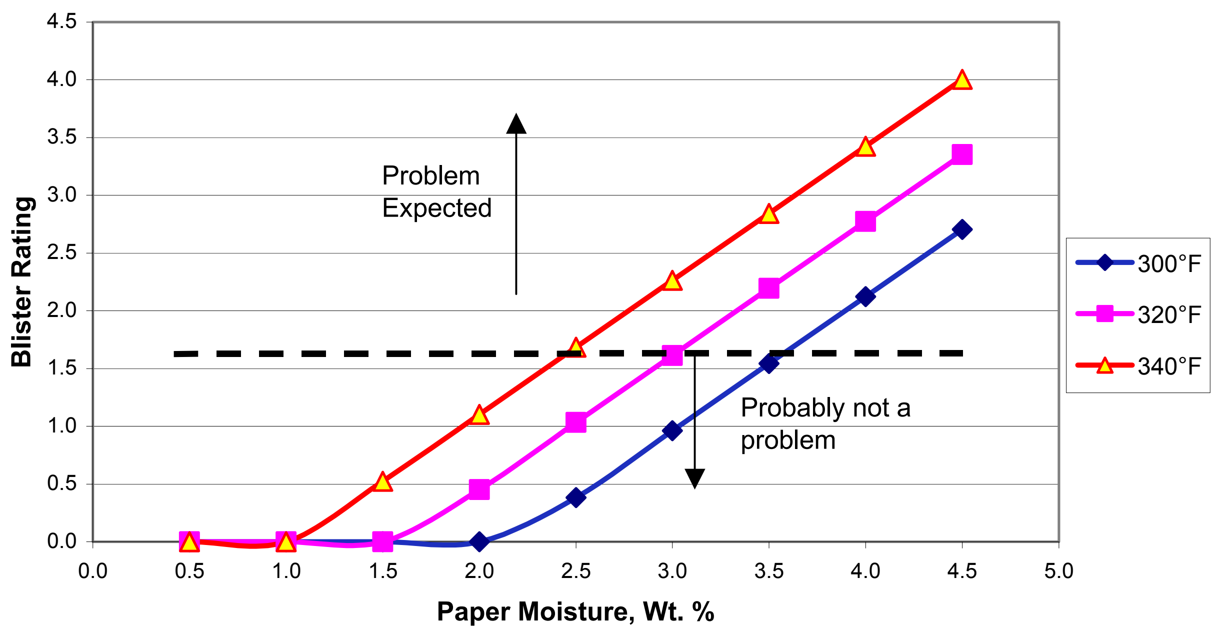


Figure 4
Blistering as a Function of Paper Moisture and Seal Temperature (Regression Result)



Regression Equation:
Blister Level = -12.2814 + 0.325397 * temp. (°F) + 1.16057 * paper moisture %
A negative result is reported as being zero

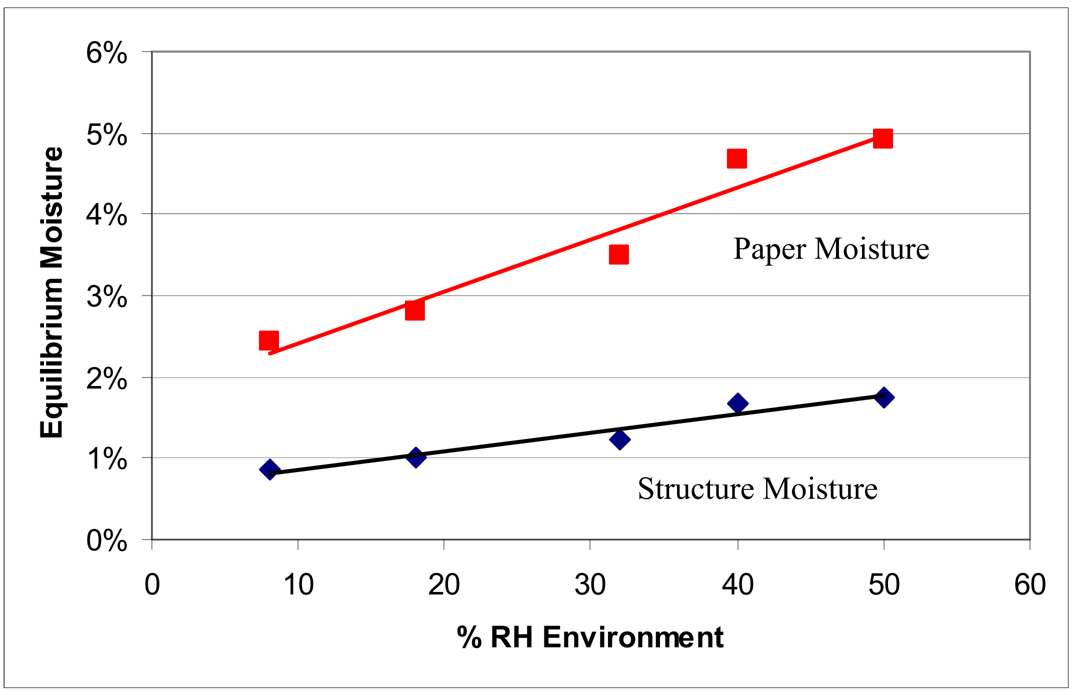
The relationship between relative humidity and paper moisture (the moisture sorption isotherm) was developed by testing the moisture level of the paper used the blistering tests (see Table III and Figure 5).

At times of the year, notably winter, indoor humidity in unconditioned areas is limited by the difference in temperature between the outside environment and comfortable indoor temperatures. When heated, moist air at 26°F (-3°C) or less will result in 68°F (20°C) air at 20% RH or lower[5]. Under such conditions, moisture barrier overwrap would not be necessary to protect paper-poly-foil-poly structures during storage where sealing temperatures are =, < 320°F (a typical condition). Because this outdoor temperature (26°F) usually cannot be planned or relied on, it is advisable to use moisture barrier packaging for storage over a few hours.

Table III
Moisture Levels in the paper of the test structure vs. Relative humidity

RH% Conditioning	Structure Moisture	Paper Moisture
8	0.86%	2.42%
18	1.00%	2.81%
32	1.24%	3.49%
40	1.66%	4.66%
50	1.75%	4.92%

Figure 5
Moisture Sorption Isotherm for Test Structure



[5] Determined using an on-line psychometric calculator at http://www.envirochex.com/psychro.htm ***envirochex*** is a Dallas-based consultant specializing in healthy indoor environments, founded by Mr. Randy Penn

Confirmation:
Four rolls, which were part of a group causing blistering and leaking packages, were sent to the converter's technical center where they were placed in a 125°F, 8% RH room for two weeks. During that time the paper moisture was reduced to ~2.5%, which should not produced blistering. These same rolls were returned to the packaging lines where the problem had formerly been noted. The rolls functioned properly as expected.

Table IV
Moisture Content of Test Rolls As Returned from Customer and After Hot Room Conditioning

Moisture Analysis of Rolls Received 11-3-03					Moisture Analysis of Rolls Dried at 8% RH 11-14-03				
Roll	Set	Cut	Total %	In Paper	Roll	Set	Cut	Total %	In Paper
5	41	3	1.53%	4.30%	5	41	3	0.86%	2.42%
5	42	1	1.59%	4.47%	5	42	1	0.97%	2.72%
5	42	2	1.76%	4.94%	5	42	2	0.90%	2.51%
5	42	6	1.61%	4.52%	5	42	6	0.86%	2.42%
		Avg:	1.62%	4.56%			Avg:	0.90%	2.52%

CONCLUSION
Paper moisture in paper-poly-foil-poly type packaging can increase when the humidity is greater than about 30% RH. Blistering is the separation of paper from the LDPE laminate and will take place when steam is released rapidly from humidified paper in a moisture barrier structure. With printed and varnished coated paper, paper moistures of about 3.8% and higher are likely to be a problem. Moisture sorption takes place fastest on outer wraps and at the edges of the stored rolls. The relationship of paper moisture to blistering was demonstrated by re-conditioning problem rolls to a lower paper moisture content and running them successfully on a packaging line.

Wrapping paper-poly-foil-poly type rolls in moisture barrier packaging will extend the shelf life of the packaging. Packaging machines with pre-heat capabilities can reduce the vulnerability of paper-poly-foil-poly type structures to blister formation and loss of abuse resistance that results when the paper is separated from the foil and sealant layers.