SPMC
Sterilization Packaging
Manufacturers Council of the
Flexible Packaging Association

Q: What effect does a pinhole in the foil layer of a foil composite have on the barrier?

A: There are a few generalizations that can be made about pinholes and aluminum foil:

1. **Pinholes exist in thin gauge foils**
2. **Pinholes in the foil layer do not have a significant effect on barrier properties.**
3. **Flexing will increase the number of pinholes in the foil layer and decrease the barrier.**
4. **Pinholes in the foil layer are not the same as through-holes in the composite.**

• Pinholes exist in thin gauge foils:
It is true that aluminum foil, even in very thin gauges, provides a total water vapor and gas barrier if in perfect condition (no pinholes or imperfections). However, aluminum foil below 1.0 mil is seldom, if ever, perfect. As the thickness of aluminum foil decreases, the number of pinholes in the aluminum foil typically increases. Typical pinhole counts in aluminum foil are:

Foil Thickness (in.)	Typical Pinhole Count/ft^2
0.00025	41
0.00030	20
0.00035	12
0.00050	6
0.00070	1
0.00100 and above	0

While few studies exist regarding the size distribution, inquiries with two foil vendors indicate that holes typically range in size from 10-50 μm in diameter. Small holes tend to be circular, while the largest holes tend to be oval in shape, with dimensions up to 75 μm by 200μm.

Visual identification of pinholes in foil depends upon the darkness of the viewing room and the quality of backlighting. The smallest hole visible with the unaided eye is generally about 10 μm in diameter. This assumes the foil is unsupported, i.e., has not yet been laminated to another web. Light interference effects due to coatings, other plies, and the adhesive/extrudate used to bond plies of a foil laminate can significantly reduce the ability of observing pinholes in foil,

- **Pinholes in the foil layer do not have a significant effect on barrier properties:**
The presence of a small pinhole or fracture or even several small pinholes or fractures in the foil layer only of a foil laminate or composite will have very little impact on the WVTR or O_2TR of the material. However, if the pinhole or fracture goes all the way through the laminate or composite, both the water vapor, gas, and sterile barriers may be lost depending upon the size of the hole.

The WVTR or O_2TR of foil composites which contain pinholes or fractures in the foil layer can be determined by actual barrier testing or estimated by calculations as shown below.

If extremely high barriers are needed, ingress through the sealant may need to be considered. The effect of ingress through the sealant on barrier can be determined by calculations as shown below or by actual barrier testing.

- **Flexing will increase the number of pinholes in the foil layer and decrease the barrier:**
In actual use, the package may flex and pinholes may develop. Different structures have varied propensities for pinholing upon flexing. This should be taken into account when determining product shelf life.

- **Pinholes in the foil layer are not the same as through-holes in the composite:**
Although the eye and most vision systems cannot distinguish between a through-hole (a hole through the entire composite) and pinholes (a hole in the foil layer (only)), they have very different effects on the barrier properties of the package. Depending upon the size of the hole, a through-hole can cause the loss of water vapor, gas, and sterile barriers. As discussed above, a pinhole has a negligible effect on the barrier. Through-holes can be distinguished from pinholes via a dye test (SPMC 004) or through internal pressurization (SPMC 005).

Addendum I. Calculating Barrier Properties of Foil Composites with Pinholes:

WVT or O_2T: The **water vapor transmission** or **oxygen transmission** through a pinhole or fracture in the foil layer (only) of a foil laminate or composite can be determined using formula (1a) or (1b) respectively.

$$\text{(1a)}\ WVT_h = \frac{(WVTR_h)(A_h)}{100} \qquad \text{(1b)}\ O_2T_h = \frac{(O_2TR_h)(A_h)}{100}$$

The **overall water vapor transmission** or **overall oxygen transmission** of a foil laminate or composite package which contains several pinholes or fractures in the foil layer (only) can be determined by using formula (2a) or (2b) respectively.

$$\text{(2a)}\ WVT_p = \frac{(WVTR_h)\left(\sum A_h\right)}{100} \qquad \text{(2b)}\ O_2T_p = \frac{(O_2TR_h)\left(\sum A_h\right)}{100}$$

WVTR or **O_2TR:** The **water vapor transmission rate or oxygen transmission rate** of a foil laminate or composite package which contains a pinhole or fracture in the foil layer (only) can be determined using formula (3a) or (3b) respectively.

$$\text{(3a)}\ WVTR_p = \frac{(WVTR_h)(A_h)}{(A_p)} \qquad \text{(3b)}\ O_2TR_p = \frac{(O_2TR_h)(A_h)}{(A_p)}$$

Likewise, the **overall water vapor transmission rate** or **overall oxygen transmission rate** of a foil laminate or composite package which contains several pinholes or fractures in the foil layer (only) can be determined using formula (4a) or (4b) respectively,

$$\text{(4a)}\ WVTR_p = \frac{(WVTR_h)\left(\sum A_h\right)}{(A_p)} \qquad \text{(4b)}\ O_2TR_p = \frac{(O_2TR_h)\left(\sum A_h\right)}{(A_p)}$$

Where A_p = The inside surface area of the package for the foil laminate being studied (square inches)

A_h = The area of the pinhole or fracture in the foil layer only (square inches)

ΣA_h = The total area of all pinholes or fractures in the foil layer only of a package (square inches)

O_2T_h = The oxygen transmission through a pinhole or fracture in the foil layer (only) of a foil laminate or composite (cc/day)

O_2T_p = The overall oxygen transmission of a foil laminate or composite package which contains pinholes or fractures in the foil layer (only) (cc/day)

O_2TR_h = The oxygen transmission rate of a laminate or composite material through a pinhole in the foil layer. The oxygen transmission rate is determined for the composite materials assuming no foil is present (cc/100 in^2/day)

O_2TR_p = The oxygen transmission rate of a foil laminate or composite package which contains a pinhole(s) or fracture(s) in the foil layer (only) (cc/100 in^2/day)

WVT_h = The water vapor transmission through a pinhole or fracture in the foil layer (only) of a foil laminate or composite (g/day)

WVT_p = The overall water vapor transmission of a foil laminate or composite package which contains pinholes or fractures in the foil layer only (g/day)

$WVTR_h$ = The water vapor transmission rate of a laminate or composite material through a pinhole in the foil layer. The water vapor transmission rate is determined for the composite materials assuming no foil is present (g/100 in^2/day)

$WVTR_p$ = The water vapor transmission rate of a foil laminate or composite package which contains a pinhole(s) or fracture(s) in the foil layer (only) (g/100 in^2/day)

Note: the above formulas do not apply and cannot be used if the pinhole goes all the way through the laminate or composite (through-hole). These can be evaluated using a dye test (SPMC 004) or through internal pressurization (SPMC 005).

Example Calculation:

Assumptions:

Foil laminate of 48 ga PET / 0.001” Foil / 0.002” low density polyethylene

6 pinholes in the foil layer each 0.005” x 0.010” in size

$WVTR_h = 0.8$ g/100 in^2/day

Package size: 6-1/2” x 12” ID Chevron Pouch

Calculation:

$$A_h = (0.005in)(0.010in) = 5.0x10^{-5}in^2$$

$$\sum A_h = (0.005in)(0.010in)(6holes) = 3.0x10^{-4}in^2$$

$$A_p \cong (75in^2/side)(2sides) = 150in^2 \text{ (I.D. area of pouch)}$$

$$WVT_h = \frac{(WVTR_h)(A_h)}{100} = \frac{(0.8g/100in^2/day)(5.0x10^{-5}in^2)}{100} = 4x10^{-7} g/day/hole$$

$$WVTR_p = \frac{(WVTR_h)(\sum A_h)}{100(A_p)} = \frac{(0.8g/100in^2/day)(3.0x10^{-4}in^2)}{(150in^2)} = 1.6x10^{-6} g/100in^2/$$

Addendum II. The effect of ingress through the seal on the barrier properties of the package.

WVTR or O_2TR: The **Water Vapor Transmission Rate** or the **Oxygen Transmission Rate** through the seal can be determined using formula 5(a) and 5(b) respectively.

$$5(a)\ WVTR_s = \frac{WVTR_m}{W_s}(0.001\,{}^{in}\!/\!_{mil}) \qquad 5(b)\ O_2TR_s = \frac{O_2TR_m}{W_s}(0.001\,{}^{in}\!/\!_{mil})$$

WVT or O_2T: The **Water Vapor Transmission** or **Oxygen Transmission** through the seal on a package can be determined using formula 6(a) and 6(b) respectively. This assumes that the same material has been used on both sides of the package.

6(a) $WVT_s = 2(t_s)(P_s)(WVTR_s)$ 6(b) $O_2T_s = 2(t_s)(P_s)(O_2TR_s)$

Where $WVTR_s$ = The water vapor transmission rate through the sealant layer of a seal of a given width (g/100in^2/day)
$WVTR_m$ = The water vapor transmission rate of the sealant material (g/100in^2/day/mil)
WVT_s = The water vapor transmission through the seal of a package (g/day)
O_2TR_s = The oxygen transmission rate through the sealant layer of a seal of a given width (cc/100in^2/day)
O_2TR_m = The oxygen transmission rate of the sealant material (cc/100in^2/day/mil)
O_2TR = The oxygen transmission through the seal of a package (cc/day)
W_s = The width of the seal (inches)
t_s = The thickness of the sealant of a laminate or composite material (inches)
P_s = The inside seal perimeter of a package (inches)

Example Calculation:

Assumptions:

Package Size: 4” x 7” I.D. rectangular pouch

Material used to construct the pouch: Foil laminate of 48 ga PET/0.001” Foil / 0.002” LDPE with no pinholes. Same material used on both sides of the pouch.

$WVTR_m$ of LDPE = 0.9 g/100in^2/day/mil

Seal Width (W_s) = 0.375”

Calculation:

$$P_s = 2(4in) + 2(7in) = 22in$$

$$WVTR_s = \frac{0.9g/100in^2/day/mil}{0.375in}(0.001\,{}^{in}\!/_{mil}) = 0.0024g/100in^2/day$$

$$WVT_s = 2(0.002in)(22in)(0.0024g/100in^2/day) = 0.000002g/day$$