APPLICATION BULLETIN

SWM

engineered for tomorrow

ArgoBond® EVA Interlayer Film

For Switchable Glass Applications

TECHNICAL CONSIDERATIONS

1. Curing Rate Kinetics
2. Starting Point Autoclave Lamination Cycles
3. Recommended Storage Practices

1. CURING RATE KINETICS OF EVA GLASS INTERLAYERS

Depending on the application and installation site, some laminated glass structures will encounter in-service temperatures that exceed the melting temperature of the EVA glass interlayer. Under those in-service conditions, unless the EVA is crosslinked, prolonged exposure to temperatures exceeding the EVA's interlayer's softening point and or melting temperature could lead to delamination or failure of the laminated glass structure.

To alleviate this possible occurrence, SWM's EVA glass interlayers are formulated to contain a peroxide curing agent having sufficient thermal stability to allow the EVA glass interlayer to flow during the early stages of the lamination cycle, wetting out the substrate surfaces and subsequently undergoing crosslinking (curing) prior to removal from the autoclave or laminator. Crosslinking is the process for converting the thermoplastic EVA into a thermoset EVA that no longer softens or flows upon the application of heat, and thus affords continued service at elevated temperatures without compromising the integrity of the laminated glass.

The curing process of EVA glass interlayer results from a hydrogen abstraction reaction. At the elevated temperatures of lamination, the peroxide curing agent thermally cleaves to yield two oxy radicals. The oxy radicals are very reactive and abstract hydrogen atoms from the EVA's polymeric chain yielding two polymer radicals. The two polymer radicals then combine to form a crosslink, commonly referred to as cure.

Analysis of the formulated EVA glass interlayer by differential scanning calorimetry (DSC) has determined that approximately 50 percent of the peroxide curative is consumed during lamination to yield a cure (gel content) level of approximately 80 percent. The 50 percent reduction in peroxide curing agent concentration measured by DSC analysis correlates to a single half-life reduction of the peroxide curing agent.

Figures 1 and 2 are presented because they are useful in designing a lamination cycle for the EVA glass interlayers. **Figure 1** depicts the half-life time of the peroxide curing agent at various process temperatures, while **Figure 2** depicts the percentage of the peroxide curing agent that will remain as a function of time and process temperature. Collectively they provide an understanding of the time/temperature relationships that are necessary for proper selection of curing parameters, i.e. lamination temperature and exposure time.

When developing a lamination process cycle, the required amount of lamination soak time at a process temperature can be determined from Figures 1 and 2 as depicted in **Table 1**.

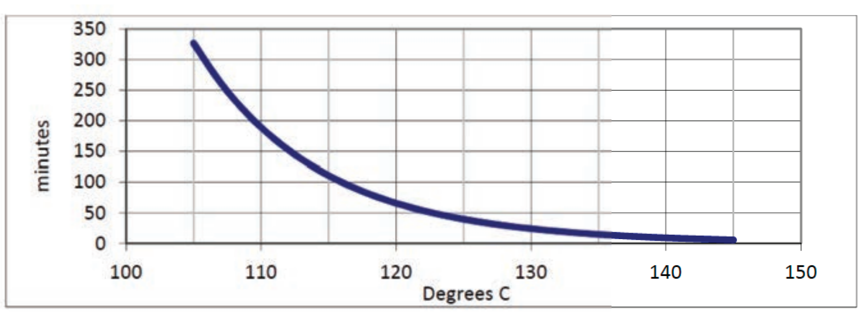

Figure 1. EVA glass interlayer's curing agent half-life (time vs. temperature)

The actual temperature attained by the EVA glass interlayer is a function of the thermal transfer of the laminate substrates to the EVA. One should take into account that the EVA temperature will always heat slower or lag behind the actual lamination device temperature due to differences in the thermal conductivity of each laminate component.

Figure 3 depicts the curing rate kinetics of a typical EVA glass interlayer as measured using a moving die rheometer (MDR). The EVA was held at a constant temperature of 302ºF/150°C for a total exposure time of 12 minutes. By cross referencing the percentage of peroxide curing agent consumed as depicted in Figure 2, it can be assumed that the torque level of 3.65 as achieved at 12 minutes in the MDR represents approximately 90 percent of the peroxide curing agent being consumed. This should not be confused with the level of cure or gel content that is achieved.

DSC analysis indicates that 50 percent of the peroxide concentration within the EVA glass interlayer is consumed when approximately 80 percent cure or gel content level is achieved. By cross referencing that 50 percent concentration with the 302ºF/150°C slope depicted in Figure 2., it can be deduced that by accomplishing an EVA temperature of 302ºF/150°C and maintaining that temperature for approximately 3.5 minutes, a cure level or gel content of approximately 80 percent will result.

Figure 4 depicts the cure levels or measured gel contents that were achieved upon curing a typical EVA glass interlayer at varying platen temperatures using dwell times of 2, 4, 6 and 8 minutes respectively. The EVA glass interlayer was cured in a Carver electrically heated hydraulic platen press.

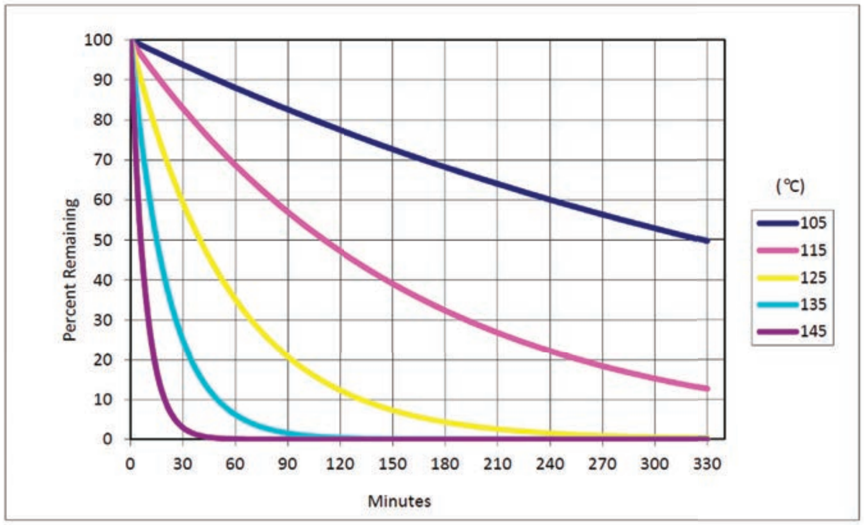

Figure 2. EVA glass interlayer's curing agent's reactivity at various temperatures

EVA Temperature	Minimum Soak Time @ Temperature
221ºF/105ºC	330 minutes
230ºF/110ºC	190 minutes
239ºF/115ºC	115 minutes
248ºF/120ºC	65 minutes
257ºF/125ºC	40 minutes
266ºF/130ºC	25 minutes
275ºF/135ºC	15 minutes
284ºF/140ºC	9 minutes
293ºF/145ºC	6.5 minutes
302ºF/150ºC	3.5 minutes

Table 1. Minimum soak time as a tunction of EVA interlayer cure temperature

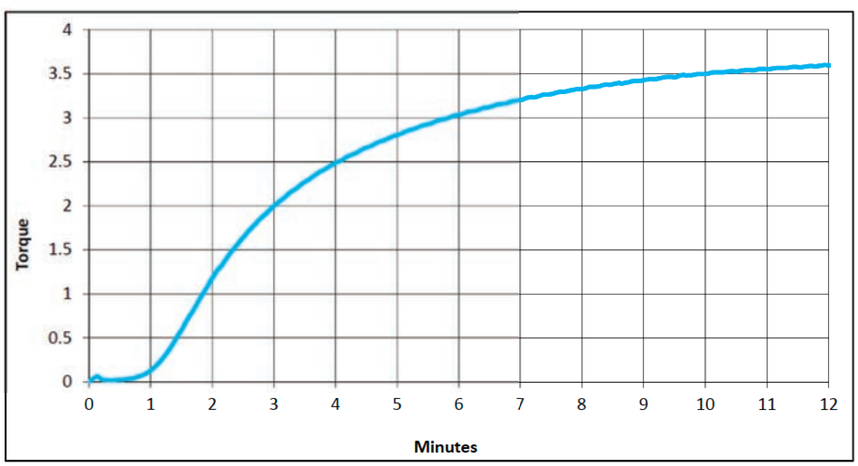

Figure 3. Curing rate kinetics of EVA glass interlayer measured by moving die rheometry (MDR) @ 302ºF/150°C

Figure 5 depicts the cure levels or measured gel contents that were achieved upon curing EVA glass interlayer at varying platen temperatures at soak times of 2, 4, 6 and 8 minutes. The EVA glass interlayer was cured in a Carver electrically heated hydraulic platen press.

While specific measurements were not made at 3.5 minutes, it is evident by the measured gel contents of EVA that was cured at 2 and 4 minutes, that a 3.5 minute exposure at 302ºF/150°C will result in an approximate 80 percent cure level or gel content. Further those parameters are supported by the curing rate kinetics data presented in Figures 1-3.

In order to establish a lamination process suited for your specific equipment it is recommended that you benchmark your equipment using a core coupon to optimize and periodically monitor your lamination equipment and processing parameters. Please refer to the diagram in **Figure 6**.

When running the lamination cycle, the core coupon should be identical to the thickest cross section of the laminate to control the cycle. Your processing parameters should be adjusted to achieve the desired core temperature and soak time per the Table above.

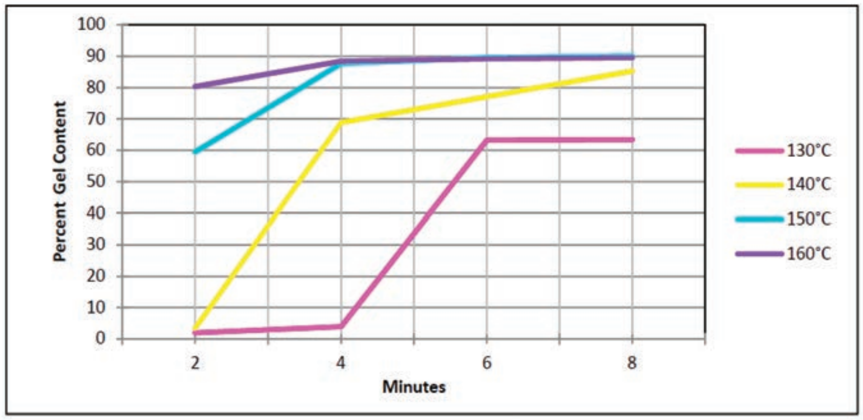

Figure 4. Cure level of a typical EVA glass interlayer at various cure temperatures and soak times

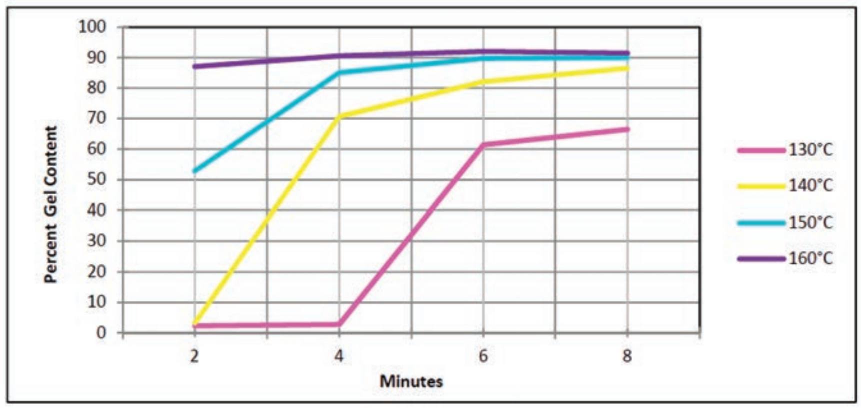

Figure 5. Cure level of typical EVA glass interlayer at various cure temperatures and soak times

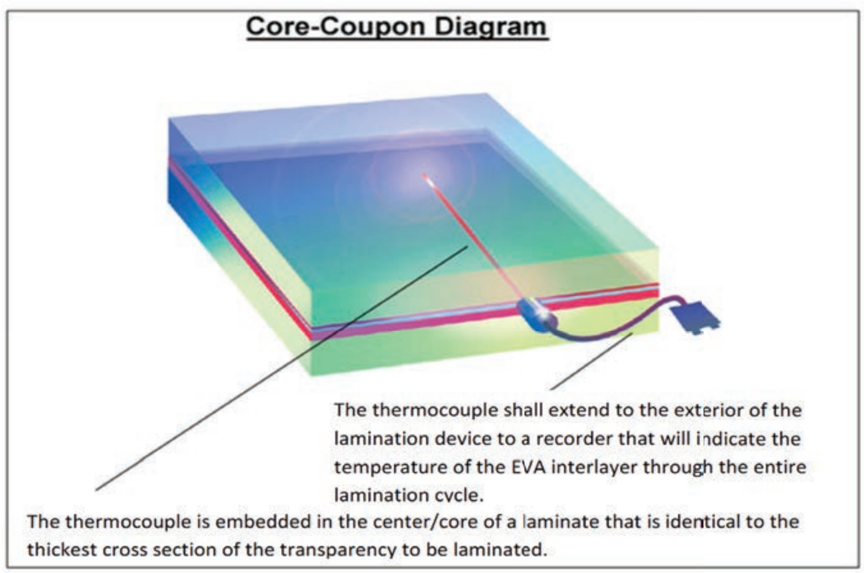

Figure 6. Cure level of typical EVA glass interlayer at various cure temperatures and soak times

2. PROPOSED STARTING POINT AUTOCLAVE LAMINATION CYCLES FOR EVA GLASS INTERLAYERS

	Time (minutes)	Temp (°F/°C)	Pressure (psi)
Pull vacuum	15	Room	Atmospheric
Ramp up	30	Room >194/90	Atm > 125 - 180
Melting time	90	194/90	125 - 180
Ramp up	10 - 15	194/90 > 239/115	125 - 180
Curing time	115 - 160	239/115	125 - 180
Cool down	Rapid Quench Cool	239/115 > Room	125 - 180 > Atm

Parts in a vacuum bag

	Time (minutes)	Temp (°F/°C)	Pressure (psi)
Pull vacuum	15	Room	Atmospheric
Ramp up	30	Room >194/90	Atm > 125 - 180
Melting time	90	194/90	125 - 180
Ramp up	10 - 15	194/90 > 266/130	125 - 180
Curing time	25 - 35	266/130	125 - 180
Cool down	Rapid Quench Cool	266/130 > Room	125 - 180 > Atm

3. RECOMMENDED STORAGE PRACTICES FOR EVA GLASS INTERLAYERS

SWM recommends maintaining EVA interlayer films in their original packaging, unopened, until it is ready for use. The rolls of EVA interlayer should be stored away from direct sunlight, and maintained below a 95ºF/35°C storage temperature.

The EVA interlayer is formulated to contain a silane coupling agent that promotes adhesion to glass and other surfaces. Unfortunately, that same silane coupling agent is hydrophilic and therefore causes the formulated EVA interlayer to be hydrophilic in nature. Therefore, unprotected EVA film will absorb atmospheric moisture which can result in a reduction of the its adhesive strength to a variety of substrate materials.

Although the amount of moisture that the EVA absorbs is dependent upon the amount of relative humidity in its immediate environment, the best recommended work practice is to prevent the EVA interlayer from being exposed to humidity to the greatest extent possible. Generally speaking, EVA sheets cut 24-48 hours in advance of their use should largely retain their original adhesive strength and only absorb a minimal amount of moisture.

However, should the EVA sheets be left unprotected for a long period of time, with increasing time, they will continue to absorb greater amounts of moisture from the environment. When the moisture content starts to saturate the EVA sheets, they will begin to display a milky white appearance. In this situation, the adhesive strength will be deteriorated by at least 50 percent and bubbles will likely form during lamination. Once the EVA sheet takes on a milky white appearance, it should be discarded.

EVA interlayer that has been stored in an uncompromised foil lined or aluminum foil wrapped package at ambient temperatures below 95ºF/35°C will remain viable for six months.

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