Leaders in the science of making good adhesives better™

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In this issue:

All about wet strength:

- What it is
- How to get it
- How to measure it

Aquaseal™ W-150 wet-strength resin

Aquaseal W-150 is our workhorse liquid thermosetting resin. It features less than 0.5 percent free formaldehyde and offers excellent pot life and low batch shock properties. Excellent water-resistant glue line protection. Promotes superior board quality, and efficient production.

Uses:

- Wet-strength corrugated board production
- Improve overall board quality for finishing

Operational benefits:

- Exceeds TAPPI 24-hour soak tests
- Convenient liquid form
- Safe and easy to use
- Compatible with automatic starch kitchens
- Distinctive red color provides visual assurance of use
- No resin shock to the adhesive
- Low free formaldehyde: complies with OSHA regulations

Use 100 pounds per 700-gallon batch. Available in 55-gallon drums, 275-gallon totes

AUGUST 2009

ADVANCED ADHESIVES REPORT

Your corrugating newsletter from Harper/Love Adhesives Corporation

Protecting against moisture

By Rex Woodville-Price

Wet strength is often viewed as an insurance policy. The thinking is, "If we add some resin to the adhesive, these boxes will be able to withstand a moist environment better." This approach makes sense and will give extra protection to boxes that may encounter a wet or humid environment anywhere in their travel from the box plant to the consumer. As insurance goes, it's pretty cheap. Eighty-five percent of the cost of a typical box is paper; adhesive is only 1% and the resin is only one-fourth of the cost of the adhesive.

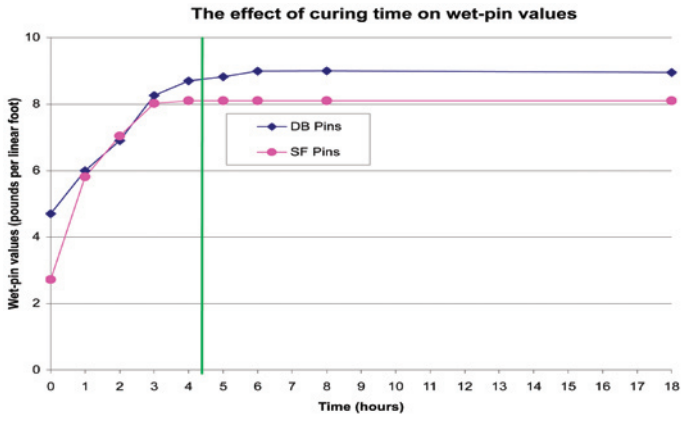
But how do we know that the level of resin addition is sufficient for the task at hand? Elsewhere in this issue we set forth some guidelines to match the amount of resin addition to the moisture resistance requirement of the boxes and how these levels are usually referred to in the industry. This gives you the addition rate, but it is not assigned a performance level. That needs to be determined through testing. (See John Kohl's article on that subject.)

Some recommendations to ensure the best possible performance from your resin:

- **Use enough resin** for the level of moisture resistance required.
- **Use a good quality resin.**
- Adhesive application rate must be increased. **Open up the gaps.** More adhesive means a shoulder is formed on the flute tip that protects the thinner pressure line in the middle. Check this by measuring the glue line width: Soak apart your board samples in warm water, then stain the glue lines with iodine to make them visible. Use a gauge to measure the glue lines; they should be between 0.080" and 0.100".
- **Run a short bridge** to keep single face web temperatures up. Once the adhesive in the glue line cools to below 130^{0}F, the reaction is complete and reheating it will not reactivate it.
- **Use freshly resinated adhesive.** Once it is mixed with the adhesive, resin has a useful life of 8 hours. Adding more resin to adhesive that has already been resinated will not work either. Only fixed amounts of resin can crosslink with the adhesive. There are a finite number of places on the starch molecule to react; once these are used up, adding more resin will not give you more wet strength.

A good wet-strength resin is cheap insurance against box failure and unhappy customers

- **Run fast, preferably to a slightly green bond.** This gets as much heat as possible into the stacks, for stack curing. (As an added benefit, running the machine fast is always good for production.) Check the temperature of the board in the stacks to verify that it has enough retained heat to ensure adequate stack cure. For typical wet strength board you will see temperatures around 180°F in the stacks.
- When transitioning from normal board to a moisture-resistant board order, the **valves should be switched at least 10,000 lineal feet (or 20 minutes) before the order comes up**, to be sure all the adhesive in the supply system (glue pans and pipes) contains resin.
- **Allow for sufficient stack curing time!** During this time the resin cross-links with the adhesive to make it less likely to break down with ambient moisture. This process starts when the adhesive gels and continues until the temperature drops to below 130°F. Remember, this process is irreversible once the temperature drops below the minimum threshold; we only get one shot at it. So even if we were to reheat the board after it cooled, we would get no further cross-linking and no additional wet strength. (See graph, below.)



Wet-strength resins are thermosetting. They need time and heat to cure. Even the best resins will not cure properly if cooled too fast. Our tests show that good thermosetting resins need 4 to 5 hours before cooling to develop a hard plastic on the glue line. Converting the stacks too early defeats the purpose of the resin, as it will not develop a water-resistant bond.

Defining wet strength

How much is enough for your customers' uses?

By Bill Kahn

The demands on corrugated containers vary widely depending on the products to be packaged. The same is true for the wet strength requirements, as some containers may need to be protected only from cyclic humidity swings in a warehouse, where other containers may need to survive transporting bananas from the growing fields of Ecuador into the hold of a ship for transport to the U.S. or Europe.

Because these demands differ so much, our industry has more or less standardized three levels of wet strength for a corrugated box.

MRA: The lowest level of wet strength is usually labeled Moisture Resistant Adhesive or MRA. MRA closely resembles domestic adhesive and is used in applications where there is no exposure to liquid water or increased humidity.

MRA contains from 0.5% to 1.0% of liquid resin relative to the liquid volume of the batch of adhesive. For a 300-gallon batch this would range from 1.5 gallons of resin to 3.0 gallons.

WRA: The next level of wet strength is called Water Resistant Adhesive or WRA. Most box plants use this type of adhesive as it provides significant improvement in the performance of the adhesive in resisting degradation due to moisture.

WRA contains from 1.0% to 1.5% of liquid resin relative to the liquid volume of the batch. For a 300-gallon batch this would range from 3.0 gallons of resin to 4.5 gallons.

WPA: The highest level of wet strength is called Water Proof Adhesive or WPA. This is somewhat a misnomer since all starches are water-soluble but this level of application is used in the extreme application of produce boxes or bulk boxes for meat or tobacco.

WPA contains from 1.5% to 2.0% of liquid resin relative to the liquid volume of the batch. For a 300-gallon batch this would range from 4.5 gallons of resin to 6.0 or more gallons.

Important: these addition rates are predicated on using a 50% solids resin such as our Aquaseal W-150. Using one of the lower solids, i.e., 35% resins on the market would increase the addition rates by as much as 43% more resin.

Testing for wet strength in the lab

By John Kohl

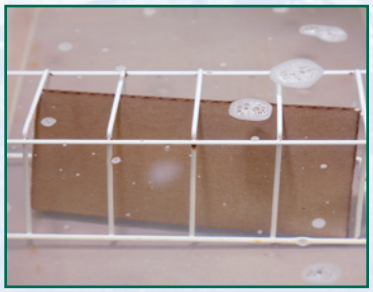
Board samples for testing should be collected from the finishing area after they have been printed. This will ensure that the resin has had the maximum possible time to cure and be most representative of the boxes the customer will receive.

Samples may be conditioned per the TAPPI standard method for conditioning, T 402, to reduce the variability in the final test results caused by seasonal changes in the weather.

24-hour soak test

The most common test used for verifying wet strength is the TAPPI test method T 812, *Ply separation of solid and corrugated fiberboard (wet)*, normally referred to as the 24-hour soak test. The test is easy to perform and is a good indicator of box and adhesive performance in a wet environment. Cut a sample 6" x 10" and place it standing vertically in room temperature (73^{0}F, ±5^0) water for 24 hours (±1 hr). Ideal test results for a water-resistant bond is to use some force to pull the liner from the medium and show some fiber tear. If the liners float apart during soaking or can be pulled off with very little force, the test can be considered a failure.

Wet pin test



The second most common laboratory (or in-plant) test is the wet pin test, a variation of the TAPPI T-821, *Pin adhesion of corrugated board by selective separation.* In this test the sample board is soaked in room temperature water for 1 hour and then the bond strength is tested with a comb like fixture inserted through the flutes in a crush tester. The results are reported in pounds of force per lineal foot of glue line tested (lbs/lin ft). Ideal test results are 1-2 lb/ft for WRA and 3-4 lb/ft for WPA.

Measuring glue lines

Measuring glue line width is also used to verify that an adequate amount of adhesive has been applied to the board to ensure good water resistance. This can

and plant

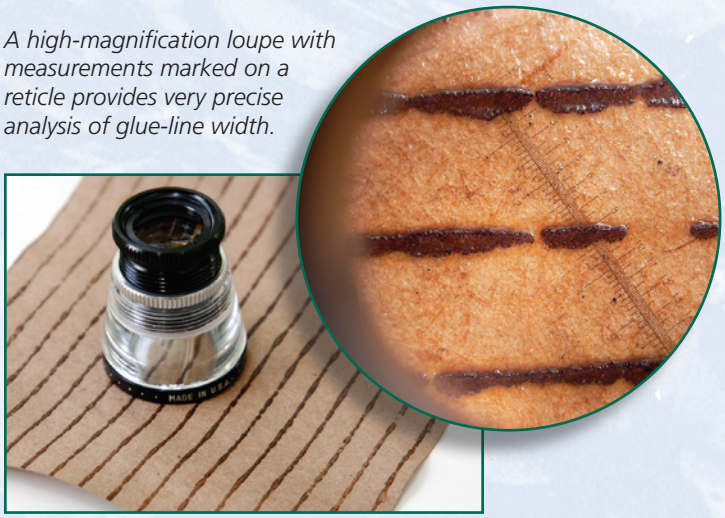
be performed at the corrugator with the use of a soak tank. Simply soak apart a piece of board and stain the glue lines with an iodine solution. Measure the width of the glue lines with a glue line gauge to verify the gap settings are open wide enough to apply adequate adhesive to the flute tips. Ideal glue line widths for water-resistant board are 0.080" for the double backer and 0.100" for the single facer.

Wet shear test

The FEFCO #9 test is a static wet shear test that measures the bond strength over a period of 72 hours. Used primarily for produce and vegetable boxes that will need high resistance to water over a long period of time. The board sample is cut into 10 strips 3/4" x 6". A hole is punched in each end, one to hang the sample from and one to hang a 250g weight from. The sample strips are slit through the liners so that the glue lines are supporting the weight. The weighted sample is submerged in room temperature water and timed until the adhesive fails and the weight falls. To pass this test the weight must stay suspended for 24 hours for full water resistance. Some plants use 48 hours or 72 hours as target times for passing depending on the box construction and end use.

Corrugated board produced with lightweight liners (lower than 42#/msf) is difficult to test for wet strength because the paper will fail before the adhesive. This is usually not an issue since boxes made for the high humidity or wet environments have higher basis weight components.

A high-magnification loupe with measurements marked on a reticle provides very precise analysis of glue-line width.



How resins work

By John Kohl

Wet strength resin (ketone aldehyde) used in corrugating adhesive is a liquid plastic that is designed to set and cure with the heat on the corrugator. As with any liquid plastic it takes a certain amount of time to completely cure out and harden, providing a water-resistant shield for the starch adhesive.

When resin is added to a starch adhesive a chemical reaction occurs called cross-linking. The hydrogen in the resin bonds to the starch molecules on available sites to create a compound that, when cured, is highly water resistant. The starch molecule has a set amount of sites with which the resin can bond. This is why, when adding too much resin, or adding it too fast, the adhesive gets very thick (resin shock). The resin is actually bonding with itself creating a high-viscosity paste.

By varying the amount of resin you can develop different levels of water resistance. The least resin (0.5% to 1.0%) will give moisture resistance, but will not make it fully waterproof, as there are some spaces in the lattice the resin creates which will allow water to pass.

Once the resinated adhesive is applied to the flute tip, and heated by the corrugator, it begins to dry and cure out. The curing process will continue as long as the board remains hot and is not allowed to cool down below 130^{0}F. This is why the corrugator needs to be running at a constant speed with a small amount of SF web on the bridge to keep the web hot.

It is also advisable to run at a speed that gives the sheets a slightly green bond on the stacker, to ensure the most heat possible in the stack at the time of discharge. Then we need to leave the board in the stack for at least 4 hours to give the resin time to harden into an insoluble plastic.

All resins are not created equal

Although most commercial resins are ketone aldehyede, there are differences that affect your production and your finished product.

Desirable characteristics in a resin:

- **Low gel time**
- **Sets quickly and completely**
- **Higher solids content**
- **Lower free formaldehyde**
- **Minimal resin shock**