# Repulpability of coated corrugated paperboard

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*A new test method demonstrates that corrugated paperboard coated with certain aqueous coatings repulps as well as uncoated corrugated paperboard.*

In the United States (and, we assume, in Europe as well), landfill space is filling up quickly and, according to the U.S. Office of Technology Assessment, paper and paperboard products account for 34% of landfill space (*1*). Consumers and governments are demanding that these materials be removed from the solid-waste stream. The obvious method is recycling.

The recycling of paper is not a new concept; it is over 300 years old in the United States alone (*2*). For the 600 paper mills in the United States, fully one-third depend almost exclusively on wastepaper, and others depend on it to a lesser degree (*2, 3*).

The repulping process is actually quite simple: wastepaper is sorted, and that which is repulpable is shipped to a paper mill where it is dispersed in water with a pulper, perhaps chemically treated, and made into new paper. The wastepaper that is not repulpable is sent to a landfill or incinerated.

The key criteria, then, for a paper to be recycled (repulped) is the ability of the wastepaper to be redispersed in the water. Untreated paper usually creates no problems. However, paper is often treated or coated to enhance its performance. In the case of corrugated, we know it is a tremendously versatile packaging performer, but even corrugated has its limitations. It is abrasive, water and moisture can penetrate it, some products will not release from it, and oil and grease can cause unsightly staining. To overcome these shortcomings, there are many treatments and coatings available such as curtain coating, wax impregnation, laminations, sizings, and water-based coatings. Paper mills have varying abilities to recycle these coated papers. Some mills can repulp items that others cannot, and there are some coated papers that no paper mill can use. One study indicated that 50% of corrugated production is recycled (*2, 3*). What happened to the remaining 50%? Was it just not collected or was it unfit for recycling by virtue of being coated?

The purpose of this paper is to study the repulpability of coated corrugated paperboard. We will describe a new test method which allows waste corrugated to be tested before it reaches the paper mill, and we will present data on the repulpability of various coatings. The ultimate goal is to provide corrugated container plants with a coating system that enhances the usability of corrugated boxes and still allows the containers to be recycled by virtually all paper mills.

I. Coatings evaluated for repulpability

| *Coating name* | *Coating description* | *Normal dry coat weight, lb/1000 ft²* |
|---|---|---|
| Uncoated | Control | 0.0 |
| Coating X300 | Water based, water resistant coating | 0.7–1.2 |
| Michem Coat 40E | Water based, gluable, general purpose coating | 0.7–1.2 |
| Michem Coat 40H | Water based, gluable, general purpose coating | 0.7–1.2 |
| Resisto Coat 39 | Water based, nonabrasive coating | 0.7–1.2 |
| Nomar 70 | Water based, gluable, nonabrasive coating | 0.7–1.2 |
| Color Coat White 2A | Water based, white pigmented coating | 1.9–3.0 |
| Curtain coating | Hot melt, general purpose coating | 6–8 |

## How repulpability is measured

The variables to consider when determining the repulpability of coated paperboard are:

- Time in the pulper
- Temperature of the water
- Chemical treatments added to the water
- pH of the water
- Specific characteristics of the pulper
- Nature of the coating–paperboard combination.

Every one of the criteria is very important and will be discussed in varying length here. It is imperative that paper mills efficiently and accurately test coated

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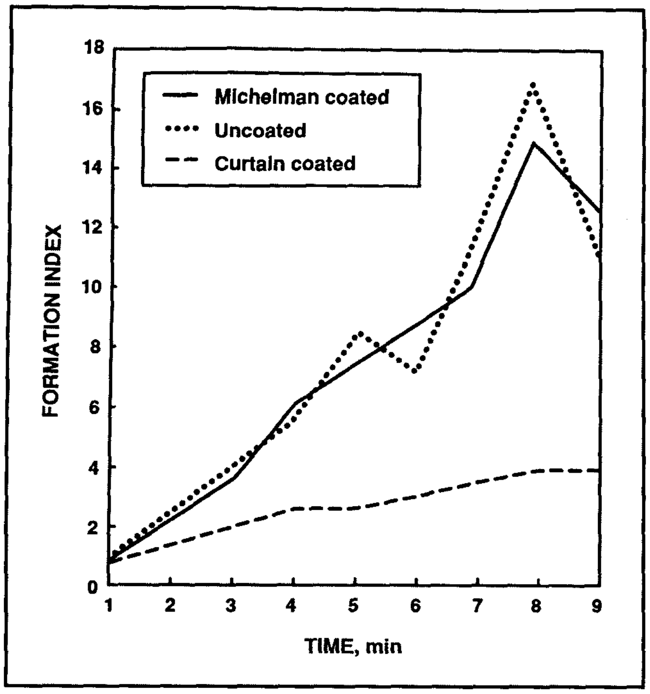
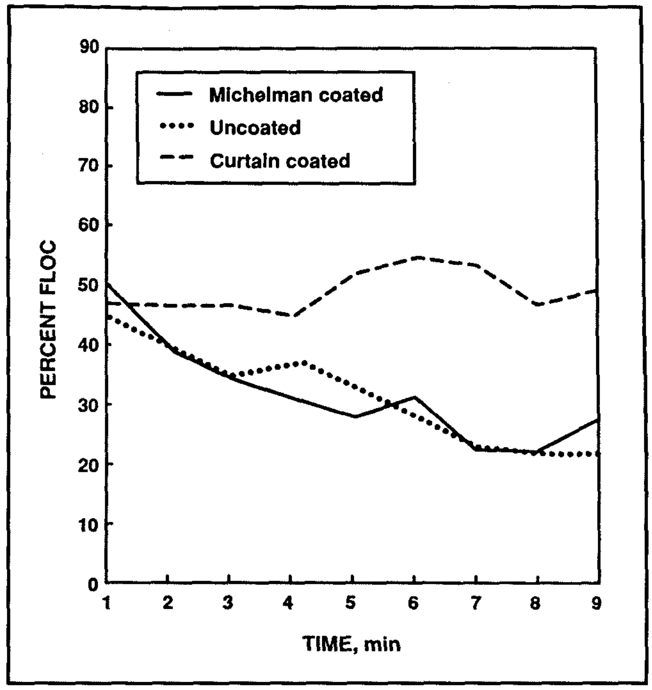
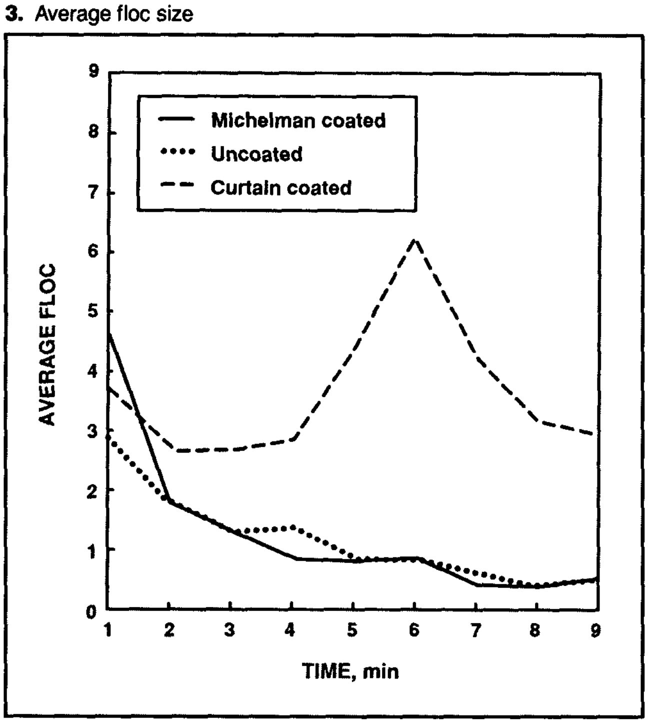
1. Formation index



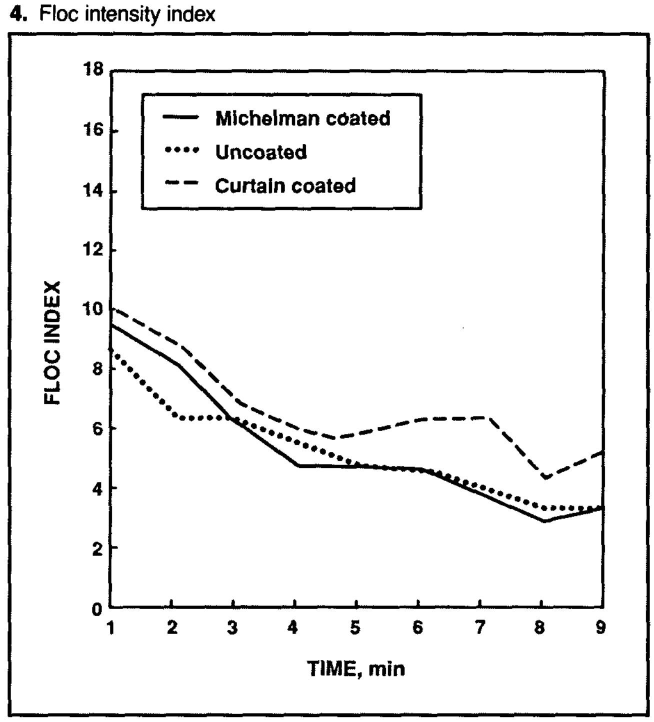

2. Percent floc




3. Average floc size




4. Floc intensity index




paperboard before it goes into the pulper on a commercial basis. Unfortunately, there is currently no recognized FEFCO standard or TAPPI test method to determine the repulpability of coated paperboard, and each paper mill seems to have its own (and sometimes proprietary) method which may meet its individual needs but may not be valid for other mills.

The American Paper Institute published a test method 15 years ago (*4*) which was the best procedure available for many years. Procedure I in this publication uses water at 38°C (100°F) and a kitchen blender for 40 seconds. It is our opinion that the blades in an ordinary kitchen blender would chop and defiber almost any waste, so it does not adequately simulate a commercial pulper. Procedure II prescribes water at 82°C (180°F), a low-speed laboratory mixer for 15 minutes after defibering starts, and the addition of sodium hydroxide plus tetrasodium pyrophosphate. The chemical addition is acceptable to some mills, but not others. However, the problem with Procedure II is the temperature; most mills are not equipped or willing to use water at 82°C (180°F). The remainder of the test involves formation of a handsheet in a Buchner funnel and visually inspecting the product for "non-defibered clumps" and the presence of other contaminants. Thus, the evaluation stage of this test is very subjective and certainly not quantitative.

## An improved test method

To respond to the shortcomings of the aforementioned test methods and to the obvious need for an accurate repulpability test method, Richard Kling of the Paper Science and Engineering Department at Miami University (Ohio) has developed a better procedure. In the Miami University test, 40 g of the paperboard are cut into 1.6-$cm^2$ pieces and placed in a British disintegrator with 2L of distilled water at a specified temperature and pH, resulting in a 2% stock. The disintegrator is described fully in TAPPI Test Method T 205 om-88, Appendix A (*5*). It consists of a stainless steel container having spiral baffles and fitted with a 3000-rpm, three-bladed propeller. The disintegrator is turned on and 125-g aliquots are removed in 1-min intervals for 9 min. Each aliquot is formed into a handsheet on a Noble & Wood handsheet machine, pressed, and dried. The product is then evaluated on an M/K Systems, Inc. microformation tester and floc/void size analyzer (*6*). A simplified description of this last procedure involves mounting the test sheet on a 20-cm-long × 10-cm-diameter glass drum illuminated on the inside by a lamp. The light transmitted perpendicularly through the sheet is passed by a focusing lens through a small aperture and onto a photocell directly behind it. As the drum rotates at 150 rpm, the light bulb and the aperture/photocell assembly are driven in tandem by a stepper motor in 0.8-mm increments parallel to its axis. Thus, an area of the sheet approximately equal to 18 cm × 25 cm is examined in about 220 almost-contiguous scan lines.

The most important feature of the instrument is the manner in which the individual light intensity measurements are handled. The readings made and stored in its memory are not measurements of absolute optical density. Rather, they are measurements of the deviations from the instantaneous mean optical density of the entire sample, which is upgraded every few milliseconds. Thus, as the scanning proceeds from a dense area such as a floc to a light area within, the basis for comparison of optical density shifts. The variations observed within the flocs and within the light zone between them, therefore, are recorded on the same scale. The data generated by the M/K formation tester allows us to calculate four characteristics of the paper:

1. Formation index: a measure of the uniformity of the handsheet
2. Percent floc: the percent of the handsheet determined to be undefibered scrap
3. Average floc size: the size of undefibered scrap
4. Floc intensity index: the difference in basis weight of the floc areas and the remainder of the handsheet.

The Miami University test method obviously addresses the main variables of concern and allows each paper mill to choose the conditions that best simulate its equipment and procedures. Even more important, we now have a quantitative evaluation method that allows correlation between paper mills.

## Results on the repulpability of coated corrugated

Miami University, in conjunction with the Michelman, Inc. laboratories in Cincinnati, investigated the repulpability of coated corrugated using the Miami University test method. In all, seven different coatings were applied to corrugated (**Table I**) and evaluated for repulpability. Six were water-based coatings, and one was a curtain coating. An uncoated sample was included as a standard.

Water-based coatings are usually composed of a combination of polymers, waxes, pigments, and as the name implies, uses water as a carrier. Because of their polymeric composition and ease of application, they are effective at lower coat weights than other systems. Water-based coatings are normally applied in-line on the corrugator, although it is not necessary to use this technique. Hot-melt coatings are composed primarily of waxes and, sometimes, small amounts of polymer to impart specific properties. They are applied in their molten stage (approximately 60-80°C) with impregnators and curtain coaters, predominantly off-line.

The experiments created 576 data points (8 samples, 2 temperatures, 4 test criteria, 9 time intervals) and, since the water-based coatings gave similar results in the four tests, a "typical" water-based coating was used to prepare **Figs. 1-4**. These graphs compare the results of the four tests at nine time intervals for water-based coated, curtain coated, and uncoated corrugated. Since the 38°C (100°F) work more closely resembles commercial paper mill temperatures, this is the only data presented and analyzed*. The water-based coated corrugated closely paralleled the uncoated in all four tests, whereas the curtain coated samples showed large deviations in uniformity (Fig. 1), amount of undefibered stock (Fig. 2), size of undefibered stock (Fig. 3), and deviations from average basis weight (Fig. 4).

Also note that at 38°C (100°F) more time in the disintegrator after 6 min did not produce significantly changed values for the four tests. Therefore, to analyze the data in a different manner, we chose to average the 6- to 9-min results to arrive at a "steady state." [The work at 82°C (180°F) also showed a leveling off, except at approximately 5 min.]

**Table II** summarizes the steady-state results as a function of coating. In the case of the formation index, percent floc, floc size, and floc intensity, there are no significant differences between the water-based coatings and the uncoated paper. The curtain coating, however, contained chunks of wax-coated paper resulting in a poor handsheet and, thus, inferior test results. There was some

*Some interesting results occurred when these studies were run at 82°C (180°F). At this temperature, the water-based coatings actually showed *better* repulpability than the uncoated corrugated. There are good explanations for this phenomenon, but they are beyond the scope of this paper.

differentiation between the coatings themselves, but nothing appreciable. (The results on a laminant, although not fully tested, also indicated the sample to be nonrepulpable. The M/K formation tester apparently had difficulty "seeing" the transparent plastic film in the handsheet, but it was quite obvious from visual inspection.)

## Conclusions

It is not surprising that curtain coated corrugated and laminations were determined to be nonrepulpable and the samples downgraded to class 11-S (*7*). The formation index, percent floc, average floc size, and floc intensity index were all inferior to the same measurements for the water-based coated products or the uncoated sample. Visual inspection confirmed these findings. The four criteria for determining repulpability of coated paperboard confirmed the repulpability of the water-based coatings used in these tests, regardless of the intended purpose of the coating. When you think about it, it does make sense. Water-based coatings do not require the high coat weights necessary for waxed or poly-laminated board. Because they lay out more efficiently, a more effective film can be formed with fewer solids. Consequently, in the repulping process there is simply less material on the board to be repulped. Additionally, because water-based coatings contain emulsifiers, they redisperse in the heated water; most of the solids remain with the water when it is drained from the fibers on the wire or the cylinder of the paper machine.

**II.** Coating type vs. repulpability measurements

| *Coating* | *Formation index* | *Percent floc* | *Floc size* | *Floc intensity* |
|---|---|---|---|---|
| Uncoated | 11.5 | 27.4 | 0.0660 | 4.16 |
| Coating X300 | 10.5 | 27.7 | 0.0672 | 3.94 |
| Michem Coat 40E | 10.5 | 29.6 | 0.0831 | 4.04 |
| Michem Coat 40H | 10.2 | 31.0 | 0.0884 | 4.11 |
| Resisto Coat 39 | 11.8 | 28.3 | 0.0688 | 4.04 |
| Nomar 70 | 9.9 | 31.1 | 0.0784 | 4.28 |
| Color Coat White 2A | 11.1 | 30.4 | 0.0784 | 4.30 |
| Curtain coating | 3.0 | 53.8 | 0.4372 | 5.96 |

*The above numbers represent an average of the 6-9 minute readings for each coating. The temperature of the repulp work for these measurements was 38°C (100°F).*

## Other considerations

Further work planned includes studies on liner without the complications of combined board (such as adhesives). More experiments involving the effect of longer pulping times at lower temperatures will also be useful. Finally, a study to correlate time in a disintegrator to time in a commercial pulper will allow the individual mill to better adapt the test methods to its particular circumstances.

Water-based systems have already proven their utility to provide water and grease resistance, lower moisture-vapor transmission rates, nonabrasive surfaces, gloss, and pigmentations in an easy to apply, nonflammable, safe product. (There are no volatile organic compounds to further pollute the environment.) New equipment for the application of water-based coatings gives high output at low costs. We now can add the documented repulpability of water-based corrugated box coatings to provide the consumer with a positive tool for solid waste management.□

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