A new laboratory method for testing paper blister in web-offset lithography

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ABSTRACT: Accurate experimental determination of blister resistance is very difficult. Many commonly used laboratory methods do not correlate to press experience, and the use of commercial press trials for testing purposes is very expensive. A new laboratory method, which can be used for either research or pass/fail testing, has been developed that simulates the commercial web-offset press process, and it has been used successfully in determining blister resistance. The method utilizes simultaneous inking on both sides of the web and ink densities that approximate 400% four-color process black. The sample is transported through a hot-air drying chamber, with computerized data gathering of both web surface and air temperatures. Oven temperature, web speed, dwell time, air-flow velocity, ink type, and ink density are controlled by the operator. This method allows for the establishment of operating parameters that mimic commercial press conditions. Commercial press trials have consistently confirmed the predictive value of the new method. Due to sample conditioning and moisture control, the new method can actually predict commercial press performance more accurately than experimentally prepared papers for press trials.

KEYWORDS: Blistering, lithography, paper tests, test equipment, test methods, web offset printing.

In recent years, activity surrounding web-offset lithography has focused on improving print quality while increasing press speed. To compensate for the increased web speed, printers have been forced to increase dryer temperatures to set the ink. This has lead to an increased prevalence of paper blister.

Paper blister is defined as "internal blowing and rupturing of the fiber matrix caused by steam generation within a paper coated on both sides (C2S) during the high-temperature drying sequence that completes the web-offset printing process" *(1)*. This circular defect within the web is visible at the same position on both sides of the sheet, has sharply defined edges, and can vary greatly in size (**Fig. 1**). Ink or coating blister can be distinguished from paper blister by the single side location of the deformation (**Fig. 2**).

As the inked paper enters the drying oven, the web temperature is raised from ambient to 150°C in one second or less. The ink solvent is vaporized, and the ink becomes set, as the internal web temperature increases. If the web is heated enough, the internal moisture turns to steam. At the moment of vaporization, either the internal bond strength of the web will withstand the pressure increase caused by the phase change (**Fig. 3**) or the steam must find an avenue of escape. Failure of the steam to escape results in paper blister (Fig. 1).

Current challenge

In recent years, many laboratory methods for measuring blister resistance *(2–4)* have been identified. Currently the most commonly used method is the hot-oil bath method *(5)*. Although hot oil immersion has been used extensively, immersing

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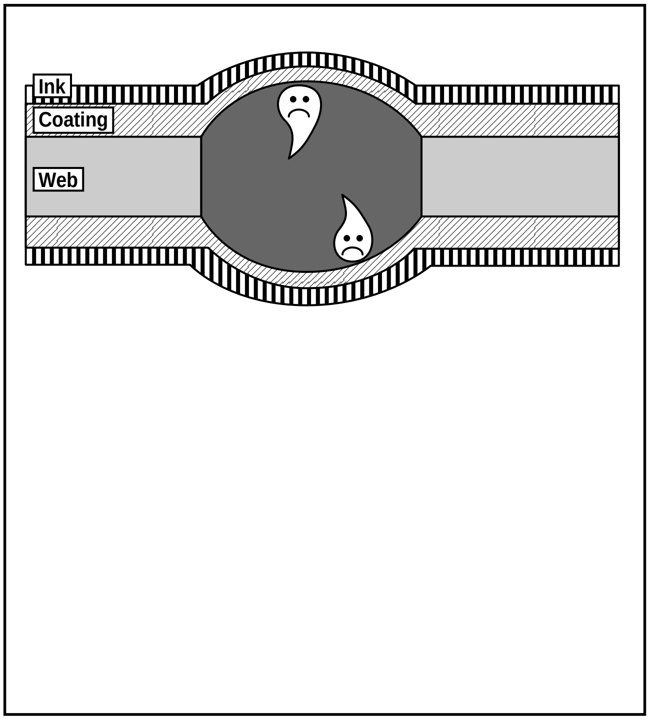
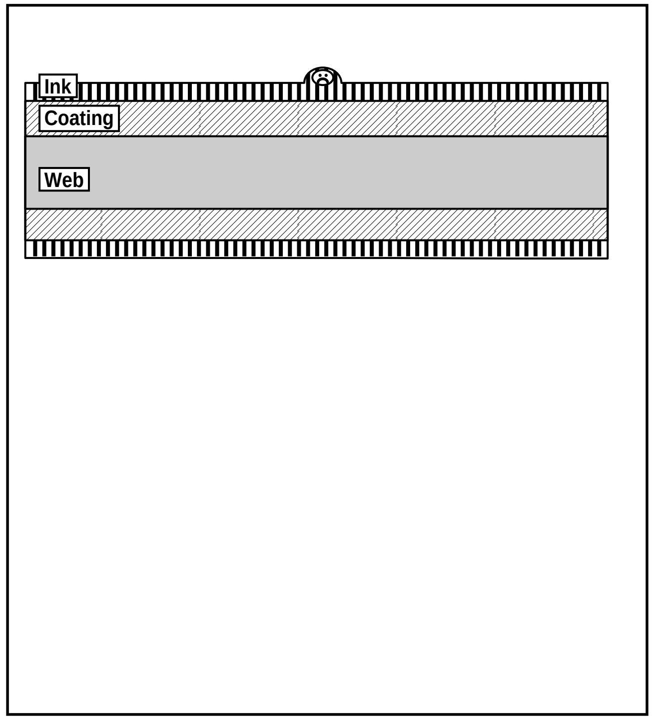
1. Paper blister



2. Ink blister



two-inch squares of coated, uninked paper into hot oil is not representative of the actual printing process, and the resulting data has not always correlated to commercial experience.

Press trials conducted on a commercial press correlate more closely with production press results but are very expensive due to preparation time, quantity of paper and ink required, and the dedication of a press and operating crew. Likewise, other important parameters, especially controlling moisture levels in the web, are difficult to control under press trial conditions.

The challenge has been to develop a laboratory method for establishing blister resistance which simulates press conditions and produces data that correlates to the commercial press experience *(6, 7)*.

New method

Sample preparation

Using the LaSeal oven and test method, the 4.5-in. x 8-in. C2S laboratory samples are first subjected to suitable temperature and humidity conditions, such that the maximum level of moisture likely to be encountered at the commercial press is obtained in the test samples *(8–10)*. For comparing data, the moisture level within any one test series must be consistent with variations of less than 0.5%. A sheet of any basis weight may be tested; however, low-basis-weight sheets (<50 lb/3300 ft^2) conditioned at 50% RH may produce very small blisters, which are more difficult to evaluate.

After moisture conditioning, a No. 2 Warren drawdown block is inked using black heatset ink. The blanket of a Little Joe *(11)* offset color swatching press is then passed over the ink film, splitting the film; one half is on the blanket and one half is on the block. A sample is attached to the inked blanket and passed back over the block. This sandwiching of the sample between the blanket and the block results in simultaneous inking on both sides of the sample. The resulting ink density is approximately 1.9, similar to a 400%, four-color process black. The blanket and the block are cleaned between each sample. Heavy or nonuniform ink coverage will result in inconsistent blister data.

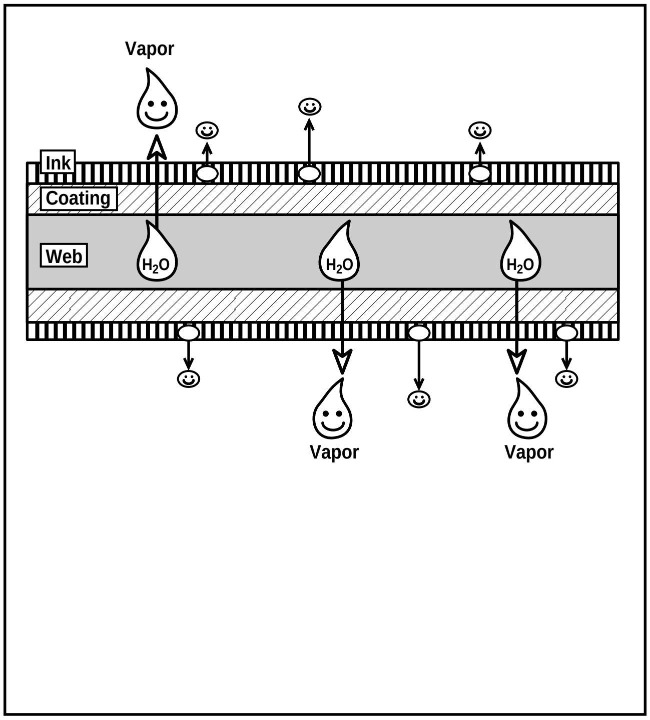
Oven design

The custom-built, 52-in. oven (**Fig. 4**) provides three variables for manipulation: air temperature, conveyor speed, and air velocity. Heaters are programmable to adjust air temperatures from ambient to >480°C. Air of regulated velocity is passed through the heaters and impinges on both the top and bottom of the sample. Air temperature is closely monitored and controlled to less than 0.20% deviation from setpoint.

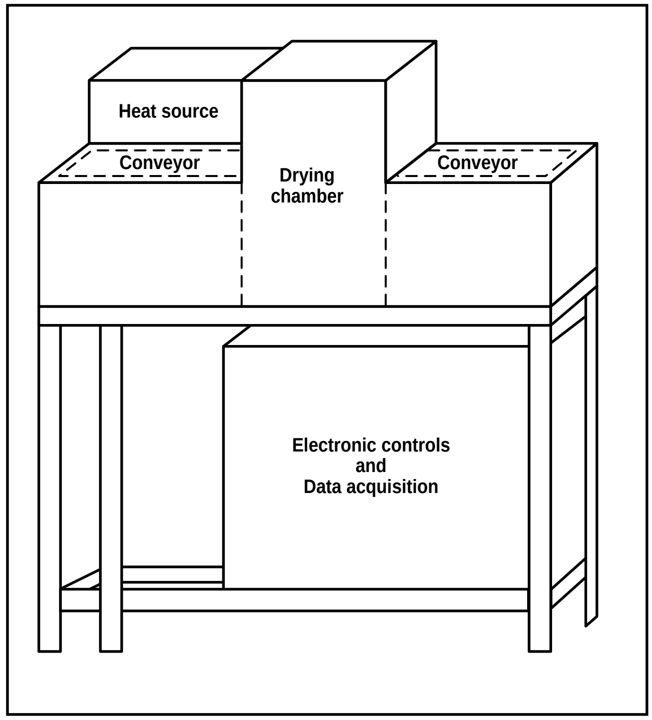
The sample is attached to an open carrier frame (**Fig. 5**) and transported through the drying chamber. The conveyor speed can be programmed for speeds up to 85 ft/min. By knowing the dimensions of the drying chamber and line speed, calculation can be made for comparison of dwell time with a commercial oven of any length (**Table I**).

An internal infrared probe, with

3. Blister resistant sheet



4. Oven design



emissivity* set to read the black inked surface, measures the surface temperature of the sample as it passes through the heated chamber.

Sample testing procedure

Initially the oven is set to reproduce a given commercial web dwell time at a given temperature. Dwell time is defined as the amount of time a sample remains within the drying chamber. As such, it is dependent on the dimensions of the drying chamber and is inversely related to conveyor speed. Dwell time must be determined within the context of sheet moisture and ink drying: i.e., conveyor speed must not be so slow as to cause the sheet to dry before entering the chamber, nor so fast as to not allow the ink to dry; both of these situations result in erroneous absence of blisters.

If the sample blisters under the initial conditions, the severity of the test must be reduced to determine the mildest conditions that result in blister. Test severity can be reduced by increasing the conveyor speed, thus decreasing dwell time, or by decreasing oven temperature. If the initial sample does not blister, the severity is increased by either increasing the oven temperature or decreasing the conveyor speed.

The following parameters are used in determining blister resistance:

1. Blister temperature: the web surface temperature obtained when the air temperature and the conveyor speed were set to the mildest conditions that still resulted in blistering.

2. Web temperature: the web surface blister temperature obtained when all samples are run at the same speed and oven temperature. This parameter allows for side-by-side comparison but gives no indication as to the severity of conditions the web can withstand.

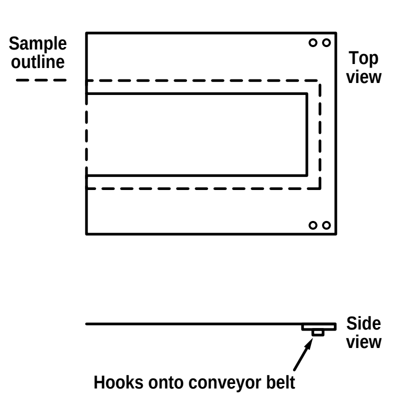
3. Dwell factor: a calculated value used to express dwell time. Dwell factor = 1/conveyor speed × 100.

4. Blister location: a calculated numerical value representing the position of the first blister visualized on the web. This value is used to separate samples only when they cannot be separated using any of the other three parameters. Blister location is calculated by measuring the distance from the leading edge of the sample to the first blister then dividing by the length of the inked sample. As web surface temperatures increase down the web, samples that are more blister-resistant tend to blister toward the end of the sheet. Therefore, a value of 0.7 indicates greater blister resistance than a value of 0.3.

Web surface temperature increases down the web as it traverses the oven. Samples that are more blister resistant blister toward the end of the test sheet; those with less resistance blister higher on the sheet. A value of 0.0 would indicate blister at the leading edge, 0.5 would be at the midpoint of the web, and 1.0 at the end.

*Emissivity is defined as the ratio of the power per unit area radiated from a surface to that radiated from a black body at the same temperature.

5. Sample holder design



I. Comparing laboratory and commercial web speeds

Laboratory web speed		*Commercial web speed*
Conveyor, ft/min	*Dwell factor*	*12-ft oven, ft/min*
50.4	2.0	2419
40.2	2.5	1930
30.0	3.3	1440
24.6	4.0	1181
20.0	5.0	960
15.0	6.7	720
11.5	8.7	470

II. First study correlation data

Laboratory data						*Commercial data*
Sample no.	*Basis weight, g/m²*	*Scott bond, ft·lb*	*Gurley porosity, s*	*Hot oil temp., °C*	*Dwell factor*	*Commercial oven, °C*
1	70	220	7560	176	3.3	162 Least resistant
2	80	186	5350	171	4.0	176
3	70	193	3660	171	4.0	176
4	70	200	7150	176	4.0	176
5	80	202	5840	171	5.0	190
6	80	214	5615	171	>6.7	>190
7	60	243	5610	176	>6.7	>190 Most resistant

Experimental

In the first study (**Table II**), seven samples, which the hot oil method of blister determination was unable to separate, were compared. Dwell factor, the parameter used in determining blister resistance, was the only variable that correlated with commercial-oven blister temperatures. The blister and web temperatures were not compared in this study because of the differences in basis weights. Laboratory-generated data measuring internal bond and porosity did not correlate with blister resistance *(12–15)*.

In the second study (**Table III**), four samples were compared which the hot oil method was unable to separate. Commercial blister temperature results from a five-color web offset press trial run at 500 ft/min were measured by a hand-held pyrometer as the web exited the oven.

To evaluate these samples in the laboratory, the paper was conditioned to 50% RH, and the black ink used during the commercial press trial was applied to seal the sheet. Dwell factor, blister temperature, and blister location were used to separate the samples.

The calculated dwell factor indicates that sample 11 has the lowest blister resistance, 14 has the highest resistance, and 12 and 13 are equal. Blister temperature was used to separate samples 12 and 13, with sample 13 being slightly more resistant. The blister location for samples

III. Second study correlation data

Laboratory data					Commercial data
Sample no.	*Dwell factor*	*Web temp., °C*	*Blister temp., °C*	*Blister location*	*Commercial web temp., °C*
11	3.3	167	166	n.a.	112
12	4.0	179	171	0.38	118
13	4.0	176	176	0.77	119
14	5.0	n.b.	187	n.a.	122

n.b.=no blister
n.a.=not applicable.

12 and 13 was determined and reconfirmed this separation.

The new test method confirmed the commercial ranking of the samples for blister resistance. There are two reasons for the recorded temperature differences between commercial press trial measurements and laboratory measurements. First, lab measurement is done inside the heating chamber while temperature measurement during commercial press trials is usually taken as the web exits the oven. Second, the emissivity of the infrared optic system within the heating chamber is optimized for the black ink it is measuring. In comparison, the hand-held pyrometer is exposed to multiple colors even though it can only be set for one.

Summary

A new laboratory method has been developed which simulates the commercial web-offset process and has been used successfully in determining blister resistance.

The method utilizes simultaneous inking on both sides of the web and ink densities that approximate 400%, four-color process black. The sample is transported through a hot-air drying chamber, with computerized gathering of both web surface and air temperature data. Oven temperature, web speed, dwell time, air flow velocity, ink type, and ink density are controlled by the operator. This method allows for the establishment of operating parameters that mimic commercial press conditions.

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