A METHOD FOR MEASURING TACK BUILD OF OFFSET PRINTING INKS ON COATED PAPER

Paul W. Concannon*
Lawrence A. Wilson*

ABSTRACT

A test method for studying tack behavior of offset printing ink on coated paper is described. Originating as a strain gage connected to a strip chart recorder, S. D. Warren's LODCEL test has evolved into a modern test system. Essential elements of the current test include a load cell force transducer, paper holding mechanism, analog-to-digital converter, Vandercook proof press and a microprocessor. The computer collects, processes and stores all data, generates hardcopy graphs of results, monitors press conditions, and enforces adherence to standard operating procedure. Options are provided for force recalibration, barcode identification, on-screen timing, and in-depth analysis of force measurements. Standard papers are used to keep LODCEL test results in statistical control. The LODCEL test has proven useful in interpreting such diverse printing phenomena as setoff, picking, carryover piling, backtrap mottle, and wet trapping.

INTRODUCTION

The ability to measure forces involved in the lithographic printing process has long been desired. Several devices have been described to measure separation forces during printing, including those reported by Borchers (1955), Swan (1973), and Franklin (1980). Recent papers by Van Gilder (1991) and Plowman (1989a) have reported test results utilizing the S. D. Warren method described below.

*S. D. Warren Company, A Subsidiary of Scott Paper Company, P. O. Box 5000, Westbrook, ME 04098-5000

The test system described herein for measuring the ink split between paper and the printing blanket was originally developed in 1974 and has undergone numerous refinements since that time. The purpose of this paper is to describe the essential elements of that test as a foundation for future papers which will use the test as a basis for interpretation of results.

TEST DESCRIPTION

To orient the reader to the test which is more fully detailed later, a general summary of the test procedure is given here:

1. Ink is applied to a printing block using a scraper; the ink is then transferred to a special blanket on a Vandercook proof press.

2. During the next minute, the test operator cleans and dries the block, attaches the test paper to the load cell, and enters a sample identification.

3. One minute after the initial ink transfer to the blanket, printing is initiated.

4. Every seven seconds after the initial print, the press cylinder is advanced, causing an ink split between the ink remaining on the blanket and that setting on the paper. As the paper is peeled from the blanket, the separation force is sensed by the load cell and recorded.

5. The test operator also observes the inked blanket for signs of coating pick. The test is terminated at ten passes or when coating failure is observed, whichever occurs first.

6. A graph of the forces versus elapsed time is generated and is used to interpret the ink/paper interaction.

Figure 1 is a photograph of one of our first test results, using a strip chart recorder for output. Note that the trace was recorded from right to left. This can be contrasted with a recent graph shown in Figure 2, which incorporates many features of computerization.

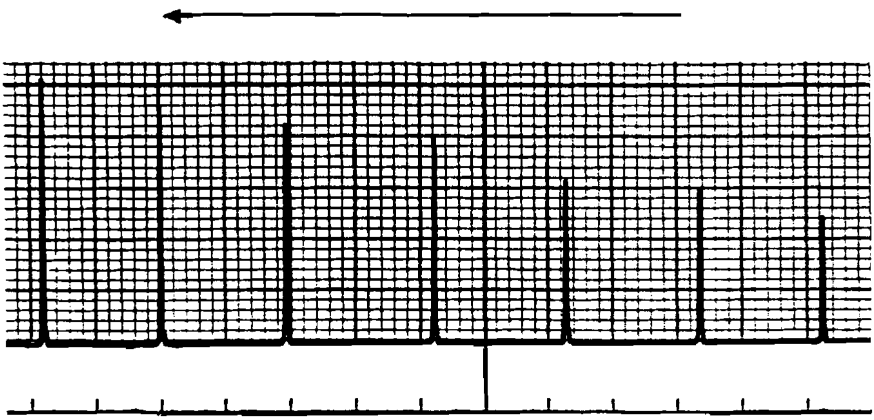

Figure 1. Strip chart recorder output from original test design; chart was recorded right to left.

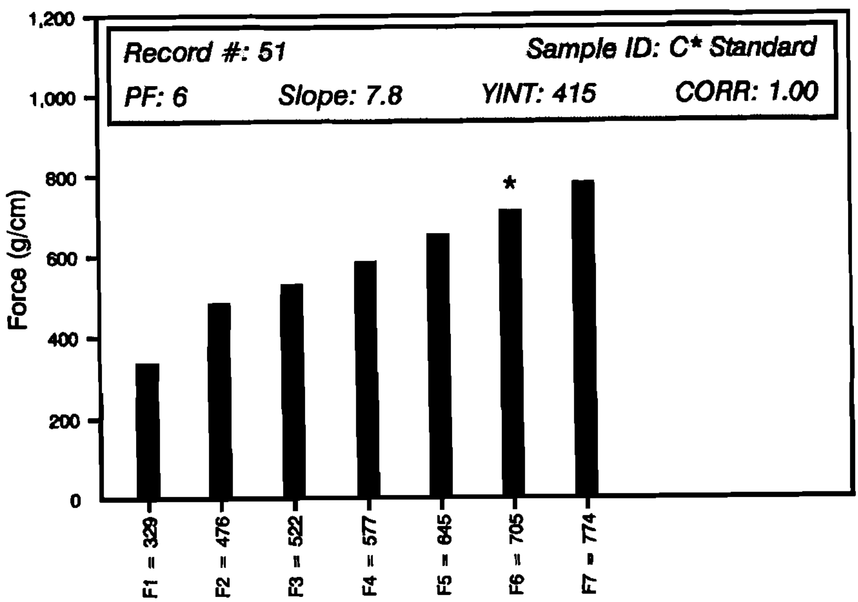

Figure 2. Simulated output from current LODCEL test system.

TEST COMPONENTS

The heart of this test method is the force measurement component. Warren's initial version of the test utilized a strain gage glued to a piece of spring steel. A number of deficiencies were identified, however, including performance decay over time.

As technology advanced, a more satisfactory approach was found which incorporated a load cell force transducer. The resultant test method has come to be called the Warren LODCEL test, and this terminology will be used to reference the overall test system as opposed to the load cell component. A general schematic of the LODCEL test equipment is depicted in Figure 3.

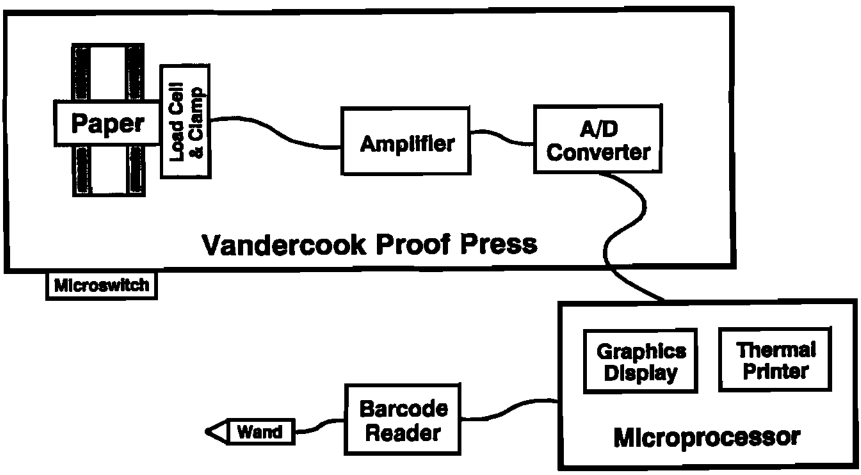

Figure 3. Simplified schematic of LODCEL test system hardware.

During early test development, separation forces were displayed on a strip chart recorder. The LODCEL test has now evolved to incorporate a microprocessor to capture, analyze and record the data.

Warren's test method uses a Vandercook proof press to accomplish the printing process. A model with automatic timing cycle and adjustable bed is considered essential for the LODCEL procedure. Special blankets have been developed to prevent ink from building tack while waiting for the printing cycle to begin. The inking procedure utilizing Warren printing blocks is well-known. The standard ink used is of our own manufacture.

A series of standard papers was developed for use with the LODCEL test, ranging from extremely fast-setting to very slow-setting. These papers are useful in interpreting behavior of various ink/paper combinations; they are also used to run daily checks in a system of Statistical Process Control.

TEST PARAMETERS

Slope

The most important information gained from a LODCEL test result is the rate of ink tack build on the paper being tested. The test parameter LODCEL slope is simply a calculation applying linear least squares regression to the time and force data. The calculation does not utilize the initial print pass, because it involves transfer of ink from the blanket to plain paper. All other forces involve a split between the inked blanket and inked paper. The calculation also rejects data from the failure pass and beyond, since those forces often drop off due to coating delamination. The correlation coefficient from the linear least squares calculation is generally greater than 0.97 for well-behaved test results.

Warren reports LODCEL force values in grams per centimeter of width. Units for slope values are thus grams/cm/second. Our LODCEL is calibrated in grams by directly attaching weights (see below).

Sample width is normally constant at 6.35 cm. Comparable results are obtained with other sample sizes, however, provided that forces observed are divided by the actual sample width, as shown in Table I.

	4.45 cm	5.1 cm	5.7 cm	6.35 cm
F1	345	343	349	344
F2	497	495	498	489
F3	541	543	542	533
F4	592	595	594	582
F5	650	652	635	639
F6	715	715	725	704
F7	780	772	783	778
SLOPE	7.3	7.6	7.8	7.2
YINT	441	439	437	434

Table I. LODCEL results for various sample widths; average of three runs, normalized for width.

Failure Pass

A second valuable LODCEL test parameter is the Failure Pass. This is simply the number of the print pass on which the operator observes coating pick on the blanket. If no failure is noted within ten passes, the designation NF (no failure) is printed on the output.

Historical data shows that a paper which fails in four or fewer passes should be of concern to the papermaker, since it might lead to tail pick, coating pick, or even delamination when printed. Of course, this is dependent on such variables as the inks used, press speeds, number of printing units, and temperature. Although there is no magic number for failure pass, the more passes achieved, the less likely a printer complaint will occur.

A general relationship exists between LODCEL slope and failure pass. High slope papers typically give few passes before failure, since the forces encountered reach a high value quickly. Conversely, low slope papers very often do not fail before the test is terminated (ten passes).

Failure Force
The failure force is most commonly the force measured on the pass where failure was observed, since the force steadily increases throughout the test. We actually report the greatest force encountered up to failure, since occasionally forces drop off at the failure pass. This parameter is somewhat imprecise because the forces observed result from discontinuous, stepwise measurements.

One could interpret failure force similar to IGT dry pick strength, but the LODCEL test involves multiple print nips as well as possible effects of ink solvent attack on paper binders. IGT dry pick failure occurs when a velocity-viscosity product is exceeded. Since the two methods provide different information, they can be used in a complementary fashion.

TEST FEATURES

Computerization of the LODCEL test allows incorporation of many useful test features, several of which are listed below:

Force Calibration
The strain gage or load cell translates the separation force of inked paper from the blanket into an electrical signal. An amplifier and analog-to-digital converter then generate data which the microprocessor can interpret. This raw signal can be converted to force units if an appropriate conversion factor is known.

One of our first attempts at calibrating the LODCEL test is depicted in Figure 4. We simply associated an observed amount of deflection with a known weight. A calibration curve was run with every set of paper samples.

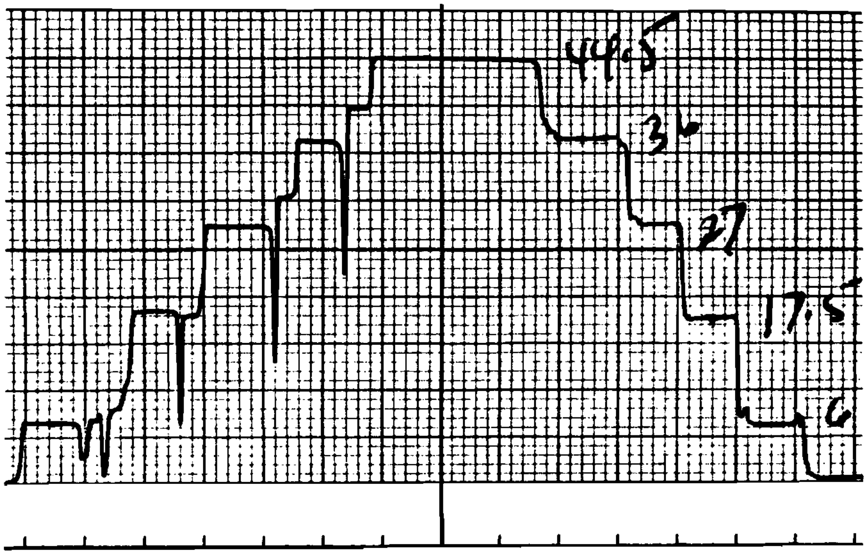

Figure 4. Calibration of early strain gage version of LODCEL test method.

We currently determine the conversion factor by executing a subroutine in the LODCEL program. The operator is stepped through the method of applying known weights to the unit and measuring the LODCEL's response. The process is repeated to obtain duplicate measurements. Figure 5 shows the extreme linearity of a typical unit during this static calibration method. The resulting calibration coefficients are stored, accessible when needed for the conversion of voltage to grams of force. As long as daily SPC results remain in statistical control, we do not recalibrate more frequently than every three months.

Voltage	Force	Residual
19	0	-0.80
44	200	0.50
94	600	3.11
144	1000	5.72
194	1400	8.33
245	1800	3.00
19	0	-0.80
44	200	0.50
95	600	-4.83
145	1000	-2.22
196	1400	-7.56
246	1800	-4.95

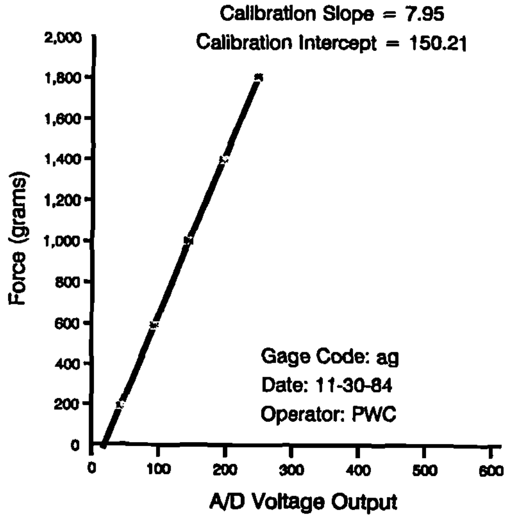

Figure 5. Generation of calibration factors for current load cell version.

Speed/Delay Calibration

The LODCEL test has been developed using a motorized Vandercook proof press. The actual press speed and the delay between passes need to be controlled for optimum results. Another computer subroutine can be accessed for adjusting these two parameters. The essential data is obtained when a sidebar attached to the blanket cylinder depresses an electronic trigger mounted on the side of the press. Knowing either the duration the trigger is depressed by the bar or the elapsed time between signals allows calculation of speed or delay, respectively.

On Screen Clock

Early versions of our LODCEL test required the press operator to activate a timer simultaneously with inking the blanket. This was a frequent source of consternation, since the clock was often not reset, and the two steps were difficult for some to coordinate.

A less stressful method allows the microprocessor to keep track of the elapsed time. Once the operator has entered the sample identification, the screen displays the time remaining. A highly audible beep sounds as a warning a few seconds prior to when the operator is required to initiate the printing operation.

Real Time Display

As the printing passes progress, the results are graphically displayed to confirm that data is being collected. The standard seven seconds between passes is ample for the computer to store the data for each pass, find the maximum force generated, convert the result to grams/cm, and display the result as a bar graph. Upon completion of the test, a hardcopy is generated. Data can also be written to an electronic file or sent directly to a database.

DETERMINATION OF PEAK FORCE

First attempts at measuring separation forces were simply to count the chart spaces of displacement on the strip chart. Slope was determined by manually drawing a "best fit" line using a straight edge and reporting rise/run (force change/time).

As test development advanced to use of a microprocessor to record and analyze data, a method for determining the peak maximum was required. During each print pass, a burst of load cell readings are collected, triggered by a microswitch. A graphical display of raw data from one such pass is shown in Figure 6.

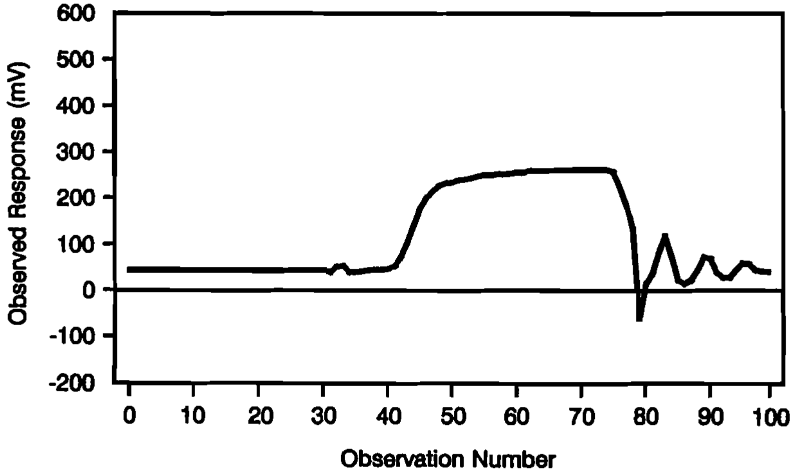

Figure 6. An individual pass response captured by the LODCEL system.

The load cell output is stable when the data collection begins; this allows a reliable calculation of a baseline. When the inked portion of the blanket contacts the paper sample, the load cell responds, and forces rise sharply as the nip width becomes fully inked. Observed forces continue to increase slightly as the blanket advances. At the moment the inked blanket separates from the printed sample, stress on the load cell is eliminated, and a rapid, oscillating return to rest is observed.

Figure 7 shows three consecutive passes superimposed. The increase in overall force values with time is apparent, while the baseline is nearly constant. A very slight movement of the release point to the right may be an indication of sample stretch.

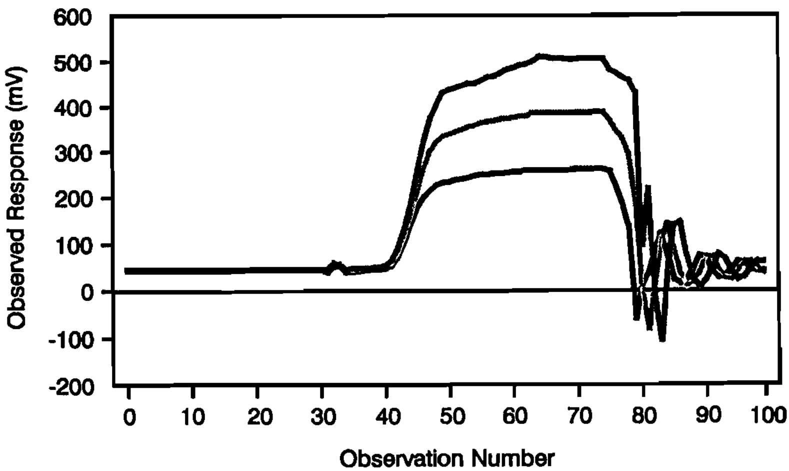

Figure 7. First three passes superimposed, showing force increase with time and possible paper stretch.

Data similar to Figure 7 is used to determine the peak force and, in conjunction with the calibration factors discussed above, graph the appropriate result.

FACTORS AFFECTING LODCEL RESULTS

Numerous factors have been identified which impact on the LODCEL results obtained. Some of the more important ones are discussed in the following paragraphs.

Press Effects

Three important variables to control are print speed, timing between passes, and printing pressure. Because computers can be excellent timers, we have chosen to let our microprocessor warn us if either speed or delay time are out of normal operating range. Printing pressure is maintained by the press operator, who must adjust the bed height between inking and printing operations.

Paper Effects
The two most significant paper properties, other than the caliper effect on pressure, are coating absorptivity and smoothness. Figure 8 shows the response of several grades of paper with differing absorption and smoothness characteristics. Note that uncoated papers are not well suited for study using this test method.

Ink Effects
Ink film thickness variation has been found to be a major influence on LODCEL test results, and attention must be given to proper training of operators in this area. Techniques for controlling variability of the standard testing ink must be employed as well.

When a variety of inks are being tested, LODCEL results are dependent on ink tack and the ink vehicle present.

Blanket Effects
The LODCEL test can also be used to study printing blanket behavior (Plowman, 1989b). Smoothness, compressibility, and absorptivity can all influence results obtained. For standard testing, a smooth, non-absorbing blanket should be used to prevent the ink from setting prematurely.

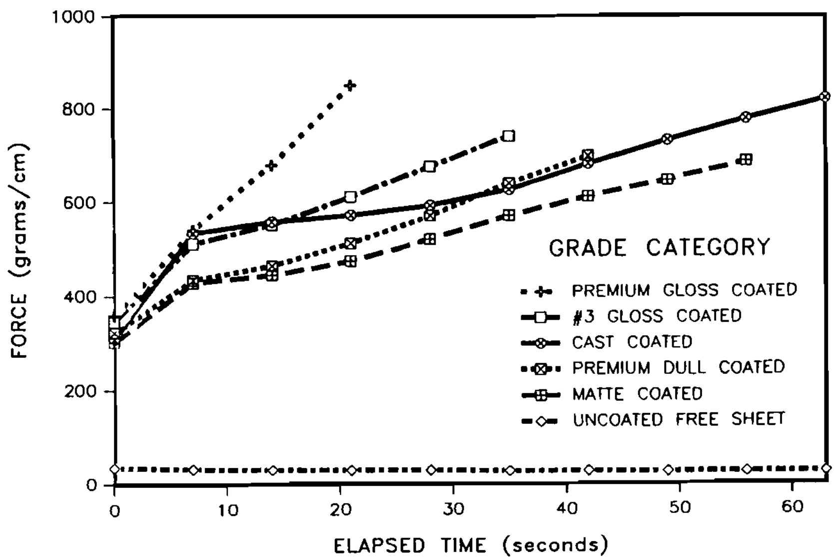

Figure 8. LODCEL response of several papers with differing absorptivity and smoothness.

Operator Effects

Proper training is the best approach to minimizing operator influence on LODCEL test results. Areas for attention are inking the block, judgment of failure, sample handling, and blanket cleaning.

Environmental Effects

Temperature can dramatically affect ink tack, and humidity has an equally strong influence on paper behavior. Adherence to temperature and humidity control conditions (50% R. H.; 20^{o} C) is advised.

TEST RELIABILITY

We have incorporated the LODCEL test into our overall program of Statistical Process Control (SPC). Despite the variability contributed by ink, paper, operator, and other sources, the test can be operated in a statistically reliable manner as demonstrated in Figure 9.

The precision of LODCEL testing is not impressive, with any slope result in question by ±15%. Failure pass results are easily repeatable within one pass. This is adequate, however, to categorize the paper setting speed (fast, normal, or slow) and coating strength (weak, normal, or strong).

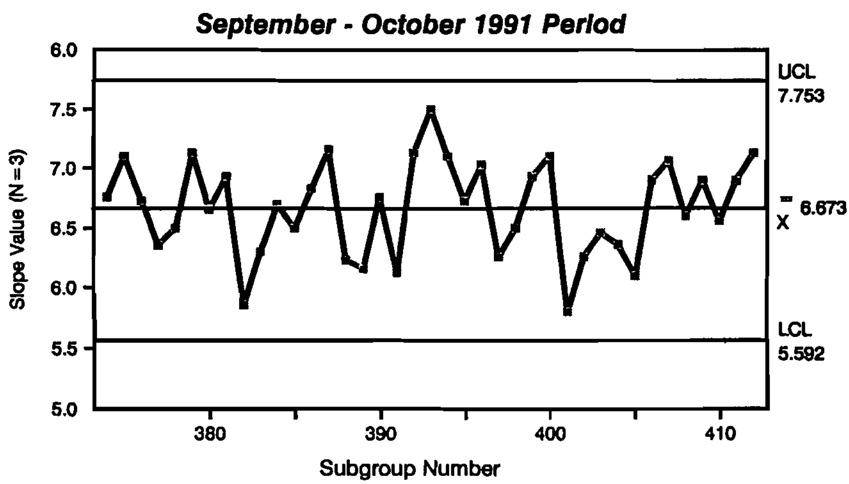

Figure 9. SPC averages chart for forty consecutive work days during which the LODCEL process was in statistical control.

INTERPRETATION OF RESULTS

A typical LODCEL test will exhibit a steady increase in forces until coating pick is observed on the blanket. Other behaviors, however, are not uncommon, and two will be discussed in more detail.

Many commercial printing inks are formulated to set quickly without developing high viscosity or tack. Their LODCEL response will often look like a mound -- rising fairly quickly, rounding off, then falling off on the other side. An example is shown in Figure 10.

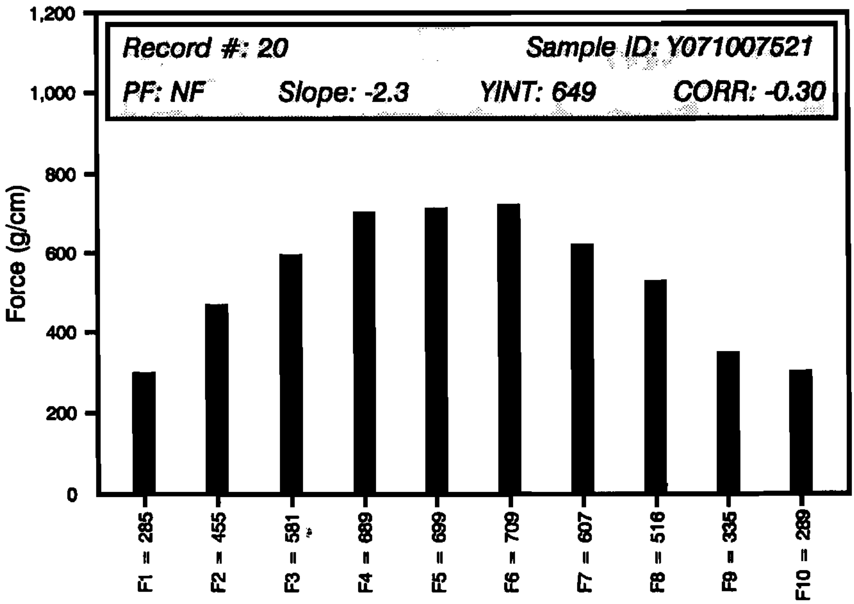

Figure 10. LODCEL graph of ink which "tacks out" before failure occurs.

Some printing papers do not interact quickly with the ink used and show a delay before tack build can occur. A graph from such a system will show a fairly flat response for several passes, followed by a rapid increase in forces. Figure 11 depicts this behavior.

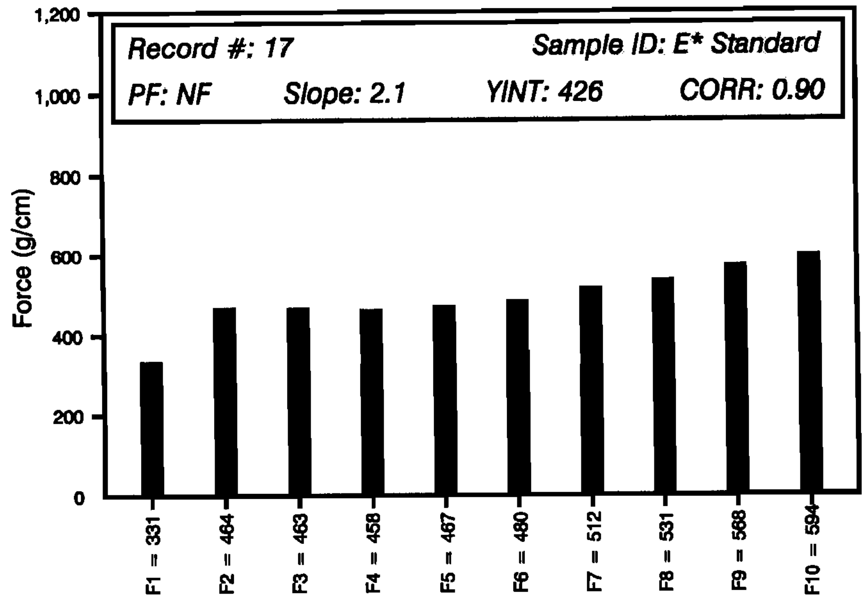

Figure 11. LODCEL graph of paper which shows a delay, then absorption rate accelerates.

A major strength of LODCEL testing lies in its flexibility to measure individual components of the printing system, as well as to study them in combination. As with any test, it has its limitations, so it is prudent to gather data from other confirmatory tests before making critical decisions.

APPLICATIONS TO PRINT PROBLEMS

In addition to its usefulness as a quality control test for monitoring production runs, LODCEL results have contributed to our understanding of the printing process. Examples are listed below.

Ink Setoff

When a sheetfed offset ink remains fluid at the paper coating surface too long, the weight of the pile will cause ink to transfer to the sheet above. This unwanted transfer results in rejected prints, or in the extreme case, in blocking.

LODCEL results can be related directly to the problem of setoff. Papers with low LODCEL slope values combined with slow setting inks can be expected to exhibit this behavior. LODCEL tests using the paper and ink involved can determine the setting behavior of the combination, or better yet, predict in advance whether special precautions will be needed.

Pick Strength

Paper manufacturers must produce coated paper with sufficient cohesion to survive the stresses of the printing process. Failure in this regard can lead to pickouts and hickies, defects that not only interfere with the print on which the pick occurs, but continue to replicate on subsequent copies.

A low LODCEL failure force is an indicator of poor dry pick strength, similar to a poor IGT pick rating. The advantage of the LODCEL system is the ability to combine the printer's ink with the paper in question. This is not normally possible for IGT tests, whose inking system requires a very stable ink or testing fluid.

Carryover Piling

Carryover piling has been described by Swan (1973) as the slow, continuous build up of paper coating and ink ingredients on the blankets of multi-color printing presses. The piling occurs in the color areas of previously printed inks. This leads to excessive washing of blankets and its resultant waste.

We have found that the LODCEL pass-to-fail failure pass is a good indicator of piling resistance. Papers which do not achieve at least four passes without failure are most likely to be involved in piling complaints. This is only a very general predictor, however, since actual performance will be influenced strongly by press design, speed, blankets, and inks used.

The success of LODCEL testing to predict carryover piling may reside in its procedure of reprinting the same sample area. By allowing the ink solvents to attack the coating binder for as much as one minute, and by repeatedly stressing the coating, we see a forecast of what might take 10,000 or more impressions on a printing press.

Backtrap Mottle

The phenomenon of backtrap mottle (BTM) has been reviewed by Eldred (1986) and its mechanism discussed by Lyne (1986). BTM occurs when ink sets in a non-uniform manner between printing units, predominantly on sheetfed presses.

LODCEL results tend to integrate the entire sample area tested, so the presence of small slow- and fast-setting areas is not indicated. It is easy to envision, however, that the presence of many fast-setting spots could lead to a high average slope value for the sample.

Our experience is that high LODCEL slope values are often found on papers which exhibit BTM. Because the occurrence of BTM may require both coating non-uniformity and fast-setting, many fast-setting papers print mottle free because of uniform ink setting.

It is equally true, however that many low LODCEL slope samples have backtrap mottling tendencies. For this to occur, the coating surface must be quite variable. The papermaker's best approach to avoiding backtrap mottle is, therefore, to produce a coated surface with uniform absorbancy.

Wet Trapping

Proper ink trapping is dependent on the effective ink tack at the moment of overprinting. This cannot be determined from inkometer curves, which relate more to tack at the time ink is transferred to the printing plate.

LODCEL tests, on the other hand, can be run with the ink and paper in question to provide insight as to why poor trap is being obtained or why one paper traps better than another, for example.

CONCLUSIONS

The LODCEL test described above has proven extremely useful for understanding ink setting behavior of lithographic inks on coated paper. By judicious choice of materials and test conditions, one can focus on any element of the printing system (paper, ink or blanket) or more importantly, on their interactions. Despite the influence of many testing variables, LODCEL results can be obtained routinely under statistical process control.

In addition to their utility in monitoring continuous production runs, we have also found LODCEL results to be extremely useful for analyzing printing complaints. Their use is not limited to identifying cause after the fact; where they have been used for pretesting materials, LODCEL results have provided knowledge which has allowed the printer to avoid problems before their occurrence.

It is our intention for this paper to serve as a prelude to additional printing research in which the LODCEL test serves as an analytical tool.

ACKNOWLEDGEMENTS

We wish to thank Peter Albert, Paul Brahms, and Joy Nannay for generating the data included in this paper. The contributions of Chuck Barr, Al Husa, Roger Morin, Pat Peoples, Ken Robie, and Dave Thomas to the technical development of the LODCEL test are gratefully acknowledged.

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