A REVIEW OF OFFSET LINTING EVALUATION

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Abstract: A review of the literature in the field of linting evaluation is presented. The terminology is defined and lint problems explained in terms of paper surface defects, print defects, pressroom problems, lint composition, and fiber length distribution of the lint.

The most important lint tests are described, and the most common test conditions specified. In order to discuss the respective value of each test when compared to offset printing, existing lint tests are classified as either non-offset or true offset printing tests with a special emphasis on bench testing. Non-offset printing tests are further differentiated as a function of the type and level of force acting on the paper surface.

The correlation - or lack thereof - between some lint tests and commercial linting is also discussed.

INTRODUCTION

Approximately 82% of daily newspapers and about 95% of weekly newspapers in North America are printed by offset [1-9]. In terms of production, in 1983, offset printing of Canadian newsprint passed the 50% mark for the first time. In 1985, nearly 55% of U.S. daily circulation was printed by offset [10].

In offset newspaper printing, linting - the tendency of paper to shed loosely bonded surface fibers and fines during printing - causes a reduction in image quality. The buildup of lint creates problems in press operation. Therefore, linting is considered to be one of the most serious paper-related problems in offset printing. Karttunen [11] has pointed out that in offset printing, linting is the most important factor affecting overall print quality, while others [12,13] suggest that low linting propensity rivals pressroom runnability as a paper requirement.

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Owing to the importance of understanding the linting propensity of paper, researchers have developed many test methods to analyze it. However, there is little agreement regarding linting mechanisms or the evaluation of test results. The precise effects of papermaking and pulping changes, or of random changes associated to mill situations with variations outside normal operation control limits, on the linting propensity of paper are not yet known. This means that the test methods and the test results often provide little help to the mill engineer who must deal with a specific lint complaint.

Four main reasons are proposed to explain the present situation.

First, the fundamental linting mechanisms have not yet been elucidated. Interpretation of test results therefore becomes difficult or even impossible when either the test conditions or the papermaking conditions change. This applies to both bench and commercial tests.

Second, bench tests used to measure linting differ too much from commercial offset printing presses.

Third, the complexity of the offset process and the fact that commercial printers control printing by the final appearance of the print make it difficult to reproduce linting experiments on a commercial unit. At least one hundred and sixty four variables are known to influence the reproduction of an offset colour print. Therefore, different printing conditions may well produce the same print quality, but different degrees of linting.

Fourth, commercial offset presses are similar to paper machines in that no two presses run alike. As only some of the variables are controlled in routine offset printing operation, it is not uncommon to find that two identical presses are being operated supposedly under the same conditions, but result in completely different lint problems.

These last two points explain the lack of agreement among researchers on the effect of either pulping, papermaking, or printing press parameters or between theories of lint buildup, even when commercial or pilot offset presses are used to measure the press-paper interactions in linting experiments.

The purpose of this report is to review the laboratory methods used to evaluate the linting propensity of pulp and papers, and to summarize present kdnowledge on offset linting evaluation. Some pulp and papermaking parameters that influence the final linting propensity of newsprint are also discussed.

Subsequent reports will present the influence of major printing presses variables for the laboratory, commercial, and pilot scale evaluation of linting, a review of existing conflicting theories on linting, and the Paprican approach to the problem of offset lint measurement based on a fundamental study of the linting mechanisms.

DEFINITIONS

Linting as a paper surface defect

During printing, forces generated in the printing nip may damage the paper surface due to the tackiness of inks and blankets. Linting, as a paper defect, refers to the accumulation of material on the offset blanket during printing. However, as linting problems related to different types and amounts of fibre accumulation may require different solutions in the papermill, paper surface defects have to be further differentiated. The most common paper surface defects, in order of increasing severity, are dusting, linting, picking, and delamination tendency.

Dust or **paper dust** refers to any unbonded fiber, fine or paper particle on the paper surface. Dust is often trapped in-between two plies of the web. It is mostly released to the air during unwinding, and ends up on the offset blanket. Usually, straightforward housekeeping in the paper mill finishing room will solve dusting problems.

Linting is defined as the tendency of the paper surface to shed loosely bonded surface fibers, fines, and vessel fragments during printing. Although linting is principally associated with offset printing, related problems are also seen in letterpress (plugging) and more recently in water-based flexography (fill-in), both of which print with similar shallow relief photopolymer plates. However, as the mechanisms that govern these problems are different, letterpress and flexography defects should be differentiated from offset linting. Finally, it should be noted that **fluff** is commonly used in Europe with the same meaning as lint in North America - see for instance the PATRA or the GFL fluff testers.

Picking means that the paper surface is damaged to such an extent that further printing is impossible because large particles - pieces of coating or paper - are pulled from the paper surface.

Delamination involves more extensive damage to the paper surface. It is usually associated with coated papers and means that the paper coating is completely removed during printing, often with one or more layers of base stock fibers.

If delamination or picking occurs on an offset press, the print run has to be aborted immediately.

Picking and delamination are related to the basic paper surface strength, and can be eliminated only by increasing surface strength and fiber bonding. Although it can be surmised that linting bears some relationship to paper surface strength and bonding, there is no simple solution, and linting remains the most pervasive of paper surface defects.

Linting as a print defect

A very important consideration in assessing the linting propensity of paper is the rate at which the print quality deteriorates. In offset printing, lint particles adhere to the tacky blanket, pick up moisture from the dampening rollers, and tend to refuse ink. Therefore, lint can be observed in printed areas as a negative image of the fibrous material agglomerated on the offset blanket. This type of print quality degradation (Figure 1) is often due to fine lint. Coarser lint (Figure 2) produces defects called "hickies" by printers. Hickies may be made of shives or fibers bundles. Dried ink is the most common non-fibrous hickey. Only the top of the hickey on the blanket surface is inked, while the surrounding area of the blanket remains uninked. The printed result is a halo also called "cat's eye" or "doughnut".

As there is as yet no objective way of defining print quality degradation due to lint, and because print defects due to lint can be confused with other defects, subjective ranking of offset prints by experienced observers has to be used [14]. Prints can also be compared to a set of standard prints which have previously-determined degrees of print deterioration.

Figure 1. The wavy appearance of the print is caused by the accumulation of fine lint on a newspaper offset blanket [99]. Flexing of the blanket causes the lint to move in waves across the blanket.

Figure 2. The "cat's eye" effect is caused by coarse lint [99].

Linting as a pressroom problem

As lint accumulates on the offset blanket, lint material starts to migrate from the blanket to the inking system

[15,16]. Owing to the affinity of cellulose or hemicellulose for water, the presence of lint in the ink prevents proper control of the ink-water balance, which results in further variations and degradation in print quality. Usually, the press is stopped before this point and the blankets are cleaned of lint.

Nowadays, printers tend to accept some degree of linting in newspapers. Elphick [15] sets a print run of 100,000 copies before a stop for blanket wash as acceptable linting. This is equivalent to about 4 times more press stops than the average 42 web breaks per 1,000 rolls reported by Page and Seth in 1982 [17]. With such a lint/web break ratio, and considering that a press stop for blanket wash costs less than a press stop due to a web break, it is fair to say that linting has at least the same economic importance as runnability.

Lint as fibrous material

Lint composition

In newspaper offset printing mechanical pulp material (mainly groundwood) (Figure 3) make up from 85 [18] to 95 percent [16] of the material accumulated on the blanket. The high content of mechanical pulp in the lint has been attributed to the low bonding potential of fiber fragments, debris, or poorly fibrillated fibers [13,16,19-23]. As mechanical pulp fines chemically resemble the portion of the wood from which they are derived [24], they can be practically pure lignin (very low bonding potential) or similar to coarse fibers in their chemical composition. The dust portion of the lint has been evaluated as 10 percent of the total lint weight [21,25] while ray cells [26] can sometimes contribute up to 80 percent [18].

In printing handsheets containing different amounts of vessels from Australian Eucalyptus on an IGT* (*see list of acronyms in Appendix) printability tester, Colley [27, 28] found that not only were vessels preferentially removed from the sheet surface but also that the vessel size, vessel to fiber ratio, the degree of beating of the vessels, and (to a lesser extent) the degree of beating of the associated fibers affected the picking tendency of vessels. Unfortunately, no attempt was made to correlate the IGT vessel picking tendency to the vessel picking tendency observed on a commercial offset printing unit.

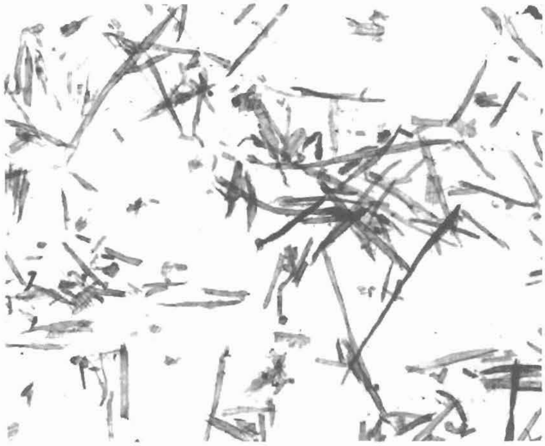

Figure 3. Dispersed lint shows mechanical pulp debris, fines, and unfibrillated stiff fibers. The lint was collected from a commercial web offset press blanket (picture by G. Williams, PPRIC).

Lint material length

The length of the lint material ranges up to about 1 mm [16,19,21] with a small fraction of fibers - usually chemical fibers [15] - above 1 mm in length. Most authors agree that about 85-90 percent of the lint debris (by number) are shorter than 0.25-0.30 mm [21,29]. However, the lint material length distribution is open to dispute. For instance, Lyne [23] found that about 50 percent of the lint by weight was retained on a 100 mesh screen whereas Ionides [13] found that about 85 percent passed through a 200 mesh screen.

Furthermore, Elphick [15] found that the composition of the lint was the same regardless of the press conditions while Larsson [16] found that the opposite was true. However, both authors agreed that lint composition is independent of run length. Larsson's claim concerning printing conditions is further substantiated by Wood [19], who noted that the nature of the lint accumulated on the blanket is a function of the printing sequence. The first unit blanket is richer in ray cells and that of the second unit is richer in clean unfibrillated short fibers. The third and fourth printing units tend to collect short chunky material.

EVALUATION OF PAPER LINTING PROPENSITY

A variety of tests exist to evaluate the linting propensity of paper, the simplest consisting of a count [30, 31] of the number of fibers protruding from a 10 cm^2 surface of unprinted paper. According to the definitions of surface defects, the "lint" tests measure surface strength-related properties of paper. The tests are divided into two main categories: (1) non-offset and (2) true-offset printing tests.

The non-offset printing tests group all tests performed on the paper without actually printing in the offset mode. Therefore, most of them do not really evaluate the offset linting propensity of papers but rather some combination of paper properties related to either dusting, picking, or linting.

In true-offset printing tests, there are two competing testing philosophies. The paper can be printed to achieve the best print quality [32], as in commercial practice, under conditions of optimized or constant print quality. Papers with different surface and bulk properties are evaluated under different printing conditions. Because the forces acting on the paper surface will vary from one paper to another, it is extremely difficult to relate linting to paper properties. Alternatively, papers can be evaluated under the same printing conditions. Although the forces acting on the paper surfaces can now be compared, this type of testing does not relate to commercial practice. Furthermore, the printing conditions may favor one paper in a group of samples, while another set of printing conditions would favor another paper. For any practical linting problem, none of these philosophies will provide, when considered alone, any definite answer.

The situation for non-offset printing tests is the same. However, the number of variables is less and the evaluation of test results is simplified. Although the most common tests and variations will be described and analyzed, some tests, developed by paper companies for internal use or in-mill tests [33] are not included in this report.

NON-OFFSET PRINTING TESTS

Non-offset printing tests simulate the force exerted by the ink at the paper surface during printing and are called force simulators [34]. Non-offset printing tests can be classified as a function of the force exerted on the paper surface. The force can act parallel to the paper surface as in abrasion or rub type tests, normal to the surface as in vacuum or plucking type tests, or as a combination of the two. Tests may involve a printing nip with or without a printing fluid. The forces acting on the paper surface are varied by using fluids with a range of viscosities, uninked printing blankets of varying tackiness, or by using different test speeds and pressures.

Vacuum tests

The edges of coated paper rolls are often vacuum cleaned before printing to reduce the amount of dust in the printing nip. The idea has been applied to test the linting propensity of both coated and uncoated papers. The surface of the moving web is vacuum cleaned, with or without brushing of the paper surface [21,35-37], for both coated and uncoated paper. Browning [21] found that an apparently efficient vacuum cleaning device can only remove a quantity of dust equivalent to about 10 percent in weight of the lint deposit. Furthermore, the lint weight accumulated on the offset blanket is not significantly reduced (about 10%) by the vacuum technique.

The dust removed from the moving web can either be weighed or visually evaluated after filtration through a black filter or black cloth, or after recovery onto an adhesive-coated glass slide. For on-line routine analysis, the dust from the flow of air can also be electrostatically charged and the resulting electric current recorded [21, 33].

The vacuum type tests are usually performed in a paper mill at the winding stage and have not been correlated with offset linting [21,33]. As paper dust contaminates the air near the offset printing press, a fixed volume of air can also be sampled and the amount of dust evaluated [38].

Dry abrasion tests

The dry abrasion tests include soft abrasion tests as the velvet pick-up or the Meret-modified PIRA rub tests, medium abrasion tests as the Taber Abraser test, and hard abrasion types such as the blade or the brush tests.

Soft abrasion tests

The velvet pick-up [36,39,40] is a soft abrasion test which removes mainly surface dust from a moving web. The testing instrument consists of a tensioning frame on which a black velvet is fixed. The system is then positioned (Figure 4) on the top of the winding or unwinding paper roll. The velvet is visually ranked against reference standards arbitrary ranging from 1 to 4.

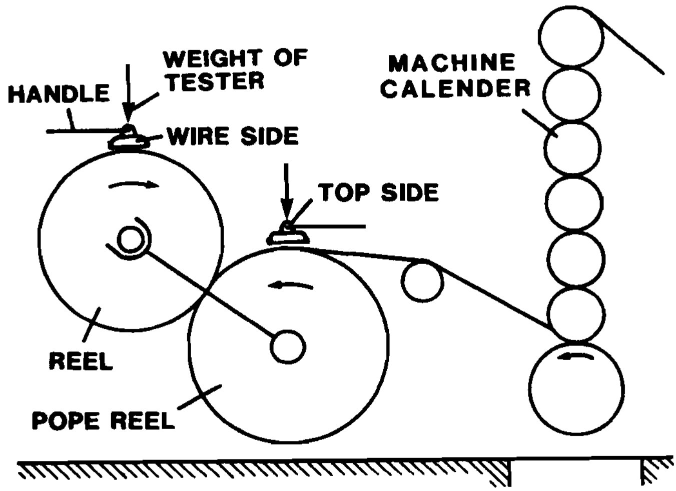

Figure 4. The velvet pick-up test performed after calendering the paper [39].

Meret [41] used the PIRA rub tester (Figure 5) to evaluate the dusting tendency of uncoated offset fine paper. To create a soft abrasion, the upper revolving disc is fitted with a black satin fabric square underpacked with a fine foam rubber. For each test, a series of 10 discs are rubbed for one minute each under a 0.74 kPa pressure. The optical density of the dust accumulated on the satin fabric is calculated from the ratio of the dusty satin and of the black satin reflectances measured with the Y-filter (545 nm) of an Elrepho photometer. The total area tested is rather small (196 cm^2 or 19.6 cm^2 per disc). Dealing with uncoated fine papers, Meret found that in a dozen pair comparison of samples, the dust test ranked papers the same way as an Harris press [41] but no correlation level was reported between the dust test and dusting on the Harris. However, Meret found that the dust test correlated well with the GFL surface strength test (see later for description).

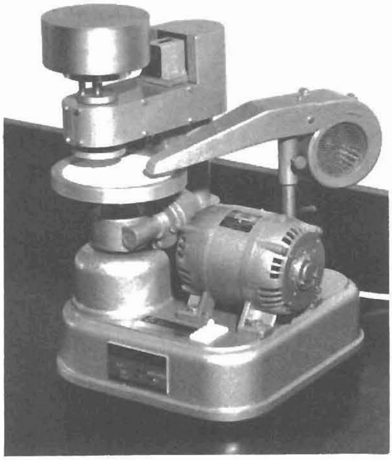

Figure 5. The Pira rub tester is used in Meret's dust test [4] and in the Elphick test [102] to rub the prints from the GFL printing unit [100].

Medium abrasion test

A medium abrasion test is performed on the Taber Abraser [37] (Figure 6) in which two rubber wheels abrade paper discs of 100 mm (4") diameter, under light pressure (0.11 kN/m or 0.65 pli) for 5 revolutions. The suction nozzle collects the material removed from the samples. The paper dust is then weighed or, to avoid including abraded rubber particles in the paper dust weight, the paper samples are weighed before and after the test. The sample tested area is 27 cm^2 (4.2 in^2).

Although the test removes about 2,000 times as much debris as is collected from the simple vacuum cleaning of the paper surface, the results of Taber Abraser could be correlated [37] to paper dust collected by vacuum cleaning the web at the slitter-winder position.

Hard abrasion tests

A hard type of abrasion is provided by the blade [42] or the brush tests [43]. In the blade test, a paper strip (224 cm^2) is mounted on a blanket fitted to the circumference of a wheel. The sample is abraded by the action of a razor blade that comes into contact with the paper surface at low angle and under a light pressure. Abrasion

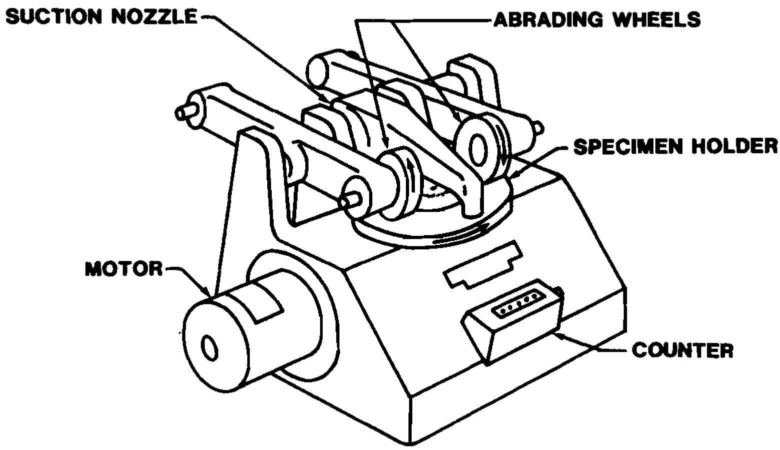

Figure 6. The Taber abraser test used as a dust test. The suction nozzle collects the material removed from the paper surface [37].

time is 1 minute at 4.7 m/s (500 rpm). Paper loss ranges from 0.1 to 1 g/m^2 of paper.

In the brush test (Figure 7), fibers and dust are removed from the paper surface by the action of a rotating nylon brush. Two samples (50 cm^2 each), mounted on two cylinders enclosed in a container, are tested for 8,000 strokes of the brush rotating at 700 rpm. The material removed is either weighed or analyzed with a microscope. Material removed ranges from 0.02 to 0.7 g/m^2.

Although neither the blade nor the brush tests have ever been correlated to offset linting, the testing principle involving frictional forces acting parallel to the paper surface may well be used nowadays to simulate the effect of the tension bands on the linting propensity of paper. Tension band lint is produced by the action of the metal bands (10 cm or 4" wide) used in newspaper pressrooms on the unwind stand to control the tension of the web.

Pulling action test

Wax tests

The simplest plucking action type of tests are undoubtedly the wax tests [44-50]. The best known of these is the Dennison wax test, in which molten waxes of different "tack" are applied to the paper surface and are allowed to

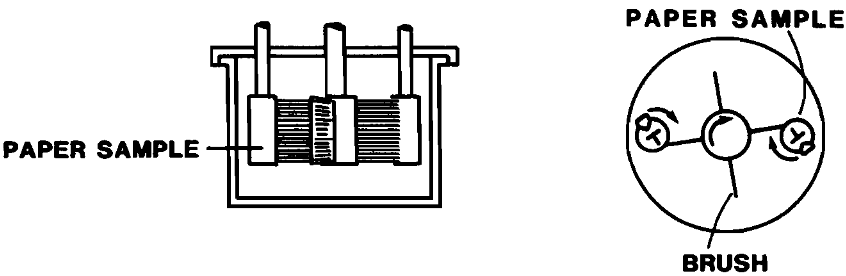

Figure 7. The brush test developed by Brecht [43] could be used to measure the tension band lint.

cool for 15 minutes. The wax and the paper are then pulled apart. The waxes are arbitrarily graded from 2A to 32A as a function of their adhesion to a casein film [46]. The average highest graded wax which does not disturb the paper surface is reported as the surface strength of the paper.

It was proven long ago [48] that the wax test cannot predict the linting tendency of paper. It is still widely used in the paperboard industry to measure surface strength. Furthermore, the correlation between the Dennison wax test and other pick tests which involve passing the paper through a printing nip is poor [48-50]. The test is mentioned here only for historical reasons.

Dry-nip tests

The dry-nip tests rely on a material tackiness, usually the adhesive tack of an offset blanket, to create the pulling force as the paper passes through an ink-free printing nip. The most common are the linting roll, the PATRA fluff tester and its modifications, and a test using a gelatin/ glycerin film as a tacky surface.

The linting roll [51] can be considered as a fair duplication of a dry printing nip since two rolls forming a soft nip evaluate both sides of the paper simultaneously. The linting roll consists of a rubber covered steel cylinder (127 mm outside diameter) fitted in a housing. For the test, the roll is brought into contact at low pressure (0.28 MPa or 40 psi) with a moving web (0.6 m/s or 120 fpm) for about 15 minutes. The dust collected on the blanket is removed with an adhesive tape and particles are counted or weighed. The change in blanket reflectance with time can also be monitored. The linting roll was compared to print degradation as a function of the number of copies printed on a commercial offset press, but, the comparison being subjective, no correlation could be established. However, the test ranked the top and the bottom side of paper in the same way as a commercial offset press, with the top side showing a greater accumulation than the bottom side.

The PATRA fluff tester [52,53] and further modifications [23,37] also use the principle of a dry nip. In the original design (Figure 8), two cylinders (15.2 cm or 6 inches diameter) are mounted on a frame. The bottom one is covered with a rubber offset blanket and driven. The pressure is applied by the weight of the cylinder and the frame, but can be increased by adding weights to the lever arm. After 5 sheets have been tested, 10 areas of 1.6 cm^2 each (¼ in^2) [54] or a 0.64 cm (¼ inch) band (30.4 cm^2) taken around the blanket circumference [23] are examined with a microscope. The number of fines or fibers larger than 0.14 mm (0.0055") [23] accumulated on the blanket are counted. About 0 to 50 such fines or fibers are removed per cm^2 of paper surface by the PATRA fluff tester. Although Pritchard [53] found that the test result was independent of the speed of rotation of the cylinders and of pressure above 3.5 kN/m (20 pli), the minimum pressure above which this is the case varies with the type of blanket used.

Using a version of the PATRA fluff tester modified [55] to better control the speed and the pressure, Lyne [23] found that the lint count decreased with increasing pressure (up to 13.2 kN/m or 75 pli) and increased with speed (up to 0.25 m/s). He also showed that the PATRA count was operator-dependent and used reflectance measurements to evaluate lint deposits on tacky polyurethane surfaces of hardness 20°, 25°, and 30° Shore A. Force was applied by a heavy roll (11.7 kg or 25.7 lbs) rolling down a 5 degree inclined plane. He found that the softer the polyurethane surface, the more material was removed from the paper surface. For instance, the 20° Shore A surface was tacky enough to delaminate the paper sheet. In a study including 13 paper samples, Lyne found that the correlation between

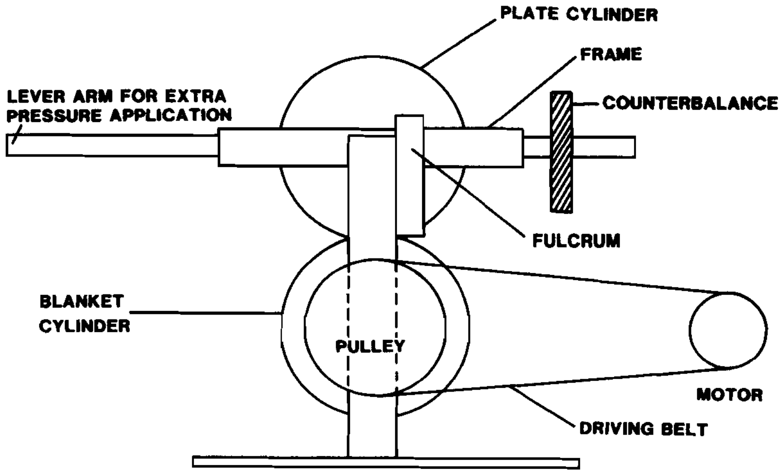

Figure 8. The PATRA (now PIRA) fluff tester [53] in its original form.

the PATRA fluff tester and a WebenDorfer four colour perfecting offset press was relatively poor [23].

However, it should be noted that the regression coefficient between lint weights originating from 2,000 and 10,000 impression runs on the press itself was only 0.77. The regression coefficient value gives an indication of a satisfactory level of correlation that could be expected between a good bench lint test and a commercial offset press.

In a test similar to the PATRA method, the IGT printability tester [37] can be used, the printing discs are then used without ink and an offset blanket has to be fastened onto the printing sector.

Unfortunately, blanket tackiness changes with time, seriously hampering the repeatability of tests relying on such principle. In an attempt to remove the blanket tackiness variable, Holte [56] used the tack of a water soluble film (gelatin/glycerin) to produce the pulling force. The film is sandwiched between a PVC (Polyvinylchloride) film and a cellulose film which is fastened to a 1.3 kg cylinder. The cylinder is fixed to a frame and the paper sample is passed at very slow speed (0.06 m/s) through a nip with the cylinder assembly on top, to provide the printing pressure, and a flat rubber blanket of 65° Shore A on the bottom, to provide the offset nip conformability. After "printing", the water soluble film is dissolved and the dust is filtered, weighed, or analysed under a microscope. The paper dust is reported as weight collected as a function of the number of passes under the roll. The amount of material removed ranges from 12 to 40 mg/m^2 of paper surface tested, comparable in weights to offset lint removal.

Wet-nip tests

The wet-nip tests include the well-known finger wet-rub, and upgraded methods, and simplified printing nips where only water is used. Although the tests are more relevant to coated papers, they have also been applied to uncoated stock.

The finger wet-rub test has been used to evaluate the dusting tendency of coated offset papers [57]. In its original form [58], drops of water were rubbed by the forefinger onto the paper surface to test the water resistance of the coating. The test could be performed with both forefinger and sample under water [59]. In order to standardize the test, the forefinger was replaced with a brush [60] (Figure 9). The sample is brushed for 40 strokes under light pressure (50 g load) and the suspended solids are measured by turbidimetry.

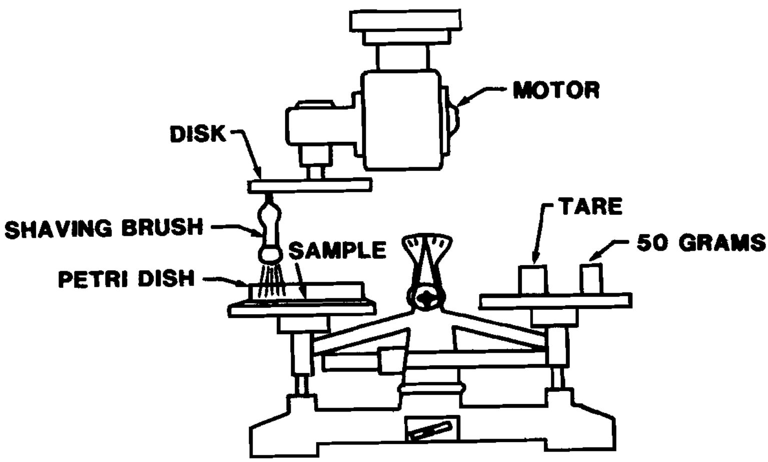

Figure 9. The system developed by Black [60] to improve the wet-rub test reproducibility.

An automated wet thumb [61] that could pick coating particles from a single sheet in a single stroke was also developed. In this test, the coating particles are transferred under dynamic pressure, established by the downstroke of a piston, to the smooth surface of a black tape previously wetted with a drop of fountain solution. The black tape is evaluated for contamination against a series of 5 standards.

In the Adams [57] method, the wet nip is formed by a rubber-covered roll rotating in a bath of water, and an upper steel wheel onto which the sample (46 cm^2 tested area) is fastened. The sample is tested for 10 seconds at 0.83 m/s. The material removed is filtered and weighed. Although the method has been used only on coated papers, it is presented here as it can be considered as an ancestor of the GFL fluff tester.

In the GFL fluff tester [62,63] (Figure 10), the paper passes between two rolls at slow speed (0.4 m/s) under a low loading pressure (0.5 kN/m or about 0.125 MPa). The upper roll is made of Teflon. The lower roll is made of stainless steel and rotates in a bath of water at room temperature. After 200 sheets, with a total surface area of 9.2 m^2, have passed between the rolls, the fluff particles trapped in the water bath are filtered through a black filter. After drying, the reflectance of the contaminated filter is measured on the Y-filter (545 nm, Filter 10) of an Elrepho reflectometer. A fluff or lint value is calculated as follows:

$$F = 1.25\ k\ \frac{Rf}{Rp} - Ro \qquad (1)$$

with,

- k: correction factor (65 for newsprint, and 85 for white fine paper),
- 1.25: instrument geometrical constant,
- Rf: reflectance of the dried fluff collected on the black filter,
- Rp: reflectance of the paper sample,
- Ro: reflectance of the black filter.

Studies performed at Paprican [64] showed that the amount of material removed by the GFL fluff tester ranges from 0.5 to 1.5 mg/m^2 of paper surface. Furthermore, the length distribution of the fluff showed that the instrument removes mainly paper dust or loose lint as found in the non-image areas of the offset blanket.

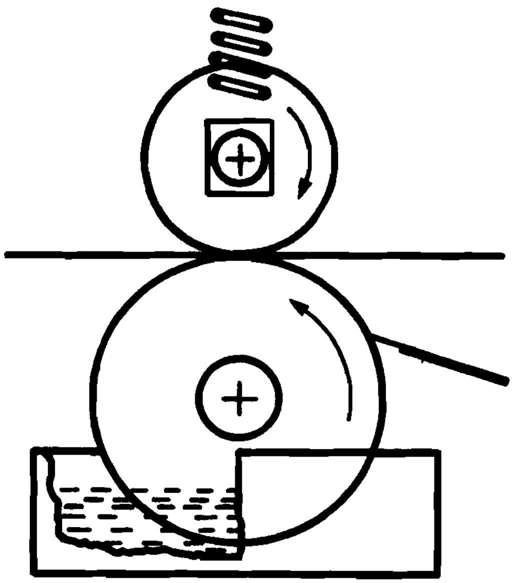

Figure 10. The GFL fluff tester [62]. The doctor blade is used to obtain an uniform film of water.

Cahierre [65] used a simplified dampening system that comes into contact with a steel cylinder covered with an offset blanket of 40° Shore A hardness. To duplicate the metal/rubber contact between the offset dampening roller and the printing plate, the backing impression cylinder is also made of steel. The system is capable of peripheral speeds ranging from 0.9 to 9.5 m/s. After 5 sheets (1 m x 0.2 m each) have passed through the nip, three representative pictures of the blanket are taken and are evaluated under a microscope. The total tested area is 10 cm^2 of blanket, corresponding to 50 cm^2 of paper surface. Particles longer than 0.2 mm are counted. The test is performed both with and without dampening. The lint is reported either as the ratio of the dry to the wet test results, or as the dry lint count. Lint counts range from 1 to 40 particles/cm^2 of paper surface. Wet counts are always lower than the dry counts, suggesting, in accordance with lubrication theory, that the tack of the wet blanket is lower than that of the dry blanket. As considered, the test is a combination of the PATRA fluff tester and of the GFL fluff tester. Although no correlation level was reported, Cahierre found that for about 70 (mainly coated) papers, a dry test count greater than 200 would give lint problems on a commercial offset press.

Picking action tests

Pick tests are pulling or plucking action type tests with the force applied to the paper surface by an ink or an oil. The most commonly used pick tests are the IGT pick test [66-69], the GFL inclined plane [70,71], and the Varkaus method [72]. Throughout the year, many test procedure modifications have appeared. The main ones include the adaptation of the rod applicator [73,74] to speed up the testing procedure, constant speed printing [75-77] to replace the accelerated IGT printability test, the use of different testing fluids [11,78-82], the adaptation of the methods to other makes of laboratory presses [11,81, 82], and the performance of the test on a previously wetted paper surface in order to duplicate offset dampening conditions [83,84]. The evaluation of the pick test, and even the theories pertaining to the test analysis differ according to various a authors [85-87]. Other related pick test methods include the pre-war Bekk method [66,88], the LTF method dry or wet [89], and the TFL method [16].

The Bekk pick test

The Bekk test can be considered as the first attempt to standardize the Dennison wax test. A strip of paper (2 x 30 cm) is glued with melted wax (shellac) to a metal bar (Figure 11). The system is designed so that there is no tension in the paper when the weight is in the vertical position. Tension is applied to the paper by manually rotating the drum to the angle when the paper surface is picked. The paper surface strength can be calculated as a function of the pick angle, the weight used in the test (1 or 2 kg), and the angle (α) between the paper and the metal bar (the greater the angle, the smaller the force required to pick the paper). Although relatively complex compared to the Dennison wax test, the Bekk test represents an improvement on the latter.

The LTF method

Another attempt to improve on the wax tests, is the LTF (now GATF) method. The LTF pick test can be performed dry [49] or with prewetting [89] of the paper surface. In the normal dry form, the tester (Figure 12) consists of a heavy flywheel (A), unbalanced by a weight (C) carrying a disc of an inked offset blanket (D). A metering block (F) provided with a recess is used to apply a 25 μm ink film to the blanket (D). The IPI tack-graded inks (1 to 8) are used in the test. The unbalanced flywheel is allowed to fall

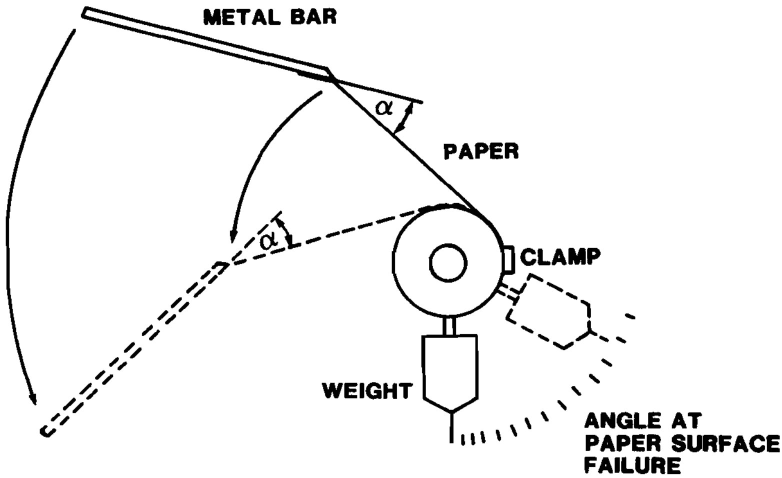

Figure 11. The Bekk tester [88] represents one of the first attempt to standardize the conditions of pick testing. The angle (α) between the paper and the metal bar can be varied.

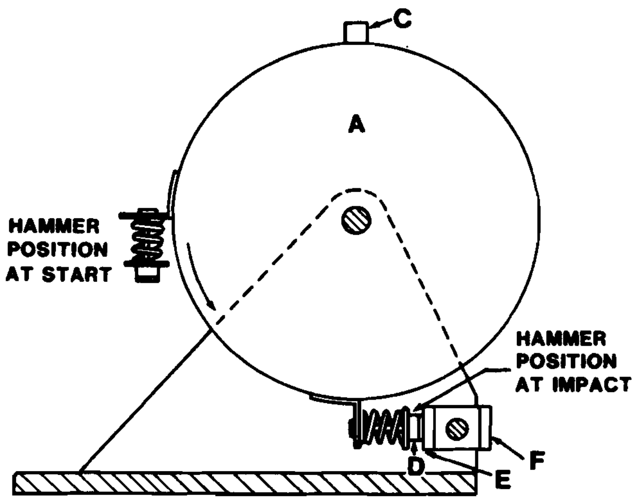

Figure 12. The LTF (now GATF) method 49] uses the rebound produced by an unbalanced flywheel hitting the paper sample. A-flywheel, C-weight, D-offset blanket, E-sample, F-metering inking block.

through a fixed arc so that it strikes the paper sample (E). The rebound, due to the reaction of the spring, produces the pick force. The spring is chosen so that blanket compression, dwell time, and separation velocity approach the average commercial printing conditions. After the pick test, samples are rated as a function of the paper surface failure. When testing coated papers (18 samples) Wheeler and Reed [49] found a rather good correlation (R_2 = 0.74) between the LTF pick test and a pick test performed on a web Harris press. However, the correlation was quite poor (R_2 = 0.40) with uncoated papers (6 samples). In fact, the pick test performed on the Harris press is no more than a sophisticated pick test. Tack-graded inks are applied directly on the offset blanket, and neither a printing plate nor a dampening solution are used in the test.

The IGT pick and modifications

In the normal IGT test, a disc inked with a tacky poly (isobutene) oil is placed under pressure against a paper sample mounted on a sector (Figure 13). The paper is then printed under acceleration from zero to a preset end-velocity. The fresh print is examined for picking under low angle illumination. For newsprint, the first signs of picking are fibers raised from the paper surface (Figure 14).

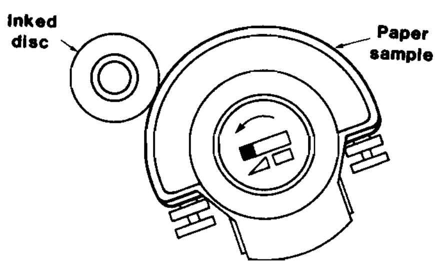

Figure 13. Configuration of the IGT printability tester [87]. The paper sample is mounted on the sector with or without backing. The IGT printability tester is used in many paper surface strength methods.

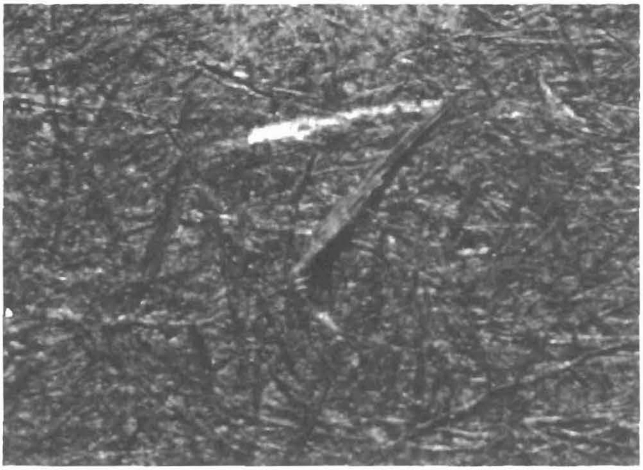

Figure 14. A pick in newsprint represented by a fiber pulled out from paper surface by the tack forces of the pick fluid [87]. Such a raised fiber will most probably **not** be removed in commercial offset printing.

The velocity at which the first [67,69,87] - or tenth [87] - pick occurs is reported as the surface strength of paper. The product of pick velocity and fluid viscosity (velocity-viscosity product of VVP) that was initially proposed [50,85,90,91] to express the paper surface strength is the center of some controversy [92,94]. Pick is linear with viscosity only for fluids of similar chemistry. In an extreme case, Aspler et al [95] reported that, even at the highest speed, high-viscosity silicone fluids were unable to cause picking of the paper surface. They also found that sector acceleration influences the pick result, and suggested that the sector end-velocity be reported as part of the test result. Different studies [87,97] of the IGT pick test reproducibility show that the operator assessment of the first point of pick is a primary potential source of error. The amount of material removed from newsprint in the IGT pick test was found [87] to range from 1.3 to 2.0 g/m^2, about one to two order of magnitude greater than in offset printing.

Due to the dependence of the VVP on the test fluid used in the pick test [92], most modifications of the method are related to the use of oils or inks of different chemistry and rheological properties. The two most commonly used test fluids are the poly(isobutene) oils [67] of differing viscosities referred to as low- (L), medium- (N), and high- (H) viscosity oils (Table I), and the IPI tack-graded (1 to 16) inks [96]. In order to better reproduce the offset printing nip conditions, Karttunen [11] uses an oil of low viscosity (5.2 Pa.s at 23°C) to reduce the level of the forces acting on the paper surface.

Similarly, the SPPP [78] advocates a gentle pick test. In the SPPP pick test, developed for routine use at the Chapelle-Darblay paper mill in France, the surface strength of paper is evaluated by counting the fibers deposited on the inked disc. In France, Lorilleux tack-graded inks (Table I), 3800-3808 series [79,80], similar to the IPI tack-graded inks, are commonly used.

TABLE I - VISCOSITY OF PICK TEST FLUIDS

Fluid		Viscosity, Pa.s at 23°C
IGT [67]		
	L	15.5
	N	54.0
	H	110.0
GFL [71]		
	L	82.6
	H	566.0
Lorilleux [80]		
Black	3800	7.5
Purple	3801	12.5
Purple Blue	3802	20.0
Blue	3803	28.0
Green	3804	32.0
Yellow	3805	44.0
Orange	3806	50.0
Red	3807	56.0
Brown	3808	80.0

Many researchers have suggested performing the pick test at constant speed in order to simplify the test evaluation. Furthermore, the ink-paper interactions in an accelerated ink transfer are not known and the ink transfer mechanism may be different from that at the constant speed of a commercial press. In the constant velocity pick test the total number of picks [75] is counted. The resulting prints can also be compared to standards [77], or the material accumulated on the inking disc is filtered and the deposits compared to standards. In his studies, Pere [76] ranked pictures of dispersed fibers resulting from a constant speed IGT pick. One obvious advantage of the last method is that a "hard copy" of the test result is conserved for future reference.

Although the IGT surface strength test can differentiate between extreme cases of linting, it evaluates more the bonding potential of the fibers than the true paper linting tendency. Correlation between the IGT pick test and commercial offset linting are sometimes announced [99] but no data supporting such conclusion could be found in the literature.

The GFL inclined plane

The GFL test is described in the Scandinavian standard SCAN-P30:70 [70,71]. The test instrument consists of a plane inclined at an angle of 17.5° covered with an offset blanket inked with a poly(isobutene) oil (Figure 15). The paper sample to be tested is fastened onto a heavy metal roll (16.8 kg, 98 mm wide, 148 mm diameter) that is allowed to go down the inked plane. The roll weight prevents speed variations that could result from drag caused by the tack of the test fluids (Table I). During the pick test, the roll accelerates to a final velocity of about 130 cm/s (260 fpm). A 10.5 μm oil film thickness is applied to the blanket with a plastic roller of 25° Shore A hardness.

After printing, the sample is examined with a magnifying glass under low angle illumination for the first signs of picking. the width of the roll allows four samples to be tested simultaneously, side-by-side. The pick test is usually expressed as the VVP [71] (viscosity- velocity product). The normal range for offset newsprint is from 4 to 14 N/m with a standard deviation of 0.1 to 0.3 N/m for 3 tests [98,99].

The picked fibers can also be collected from the blanket, filtered, and weighed. The fiber weights range from 0.1 to 1.5 g/m^2. As the linting becomes worse, weighing the fibers is more sensitive [99] than evaluating the location of the first pick. Meret [98] reports a 0.53 regression coefficient between the GFL pick and commercial offset lint evaluation (30 samples, no data reported).

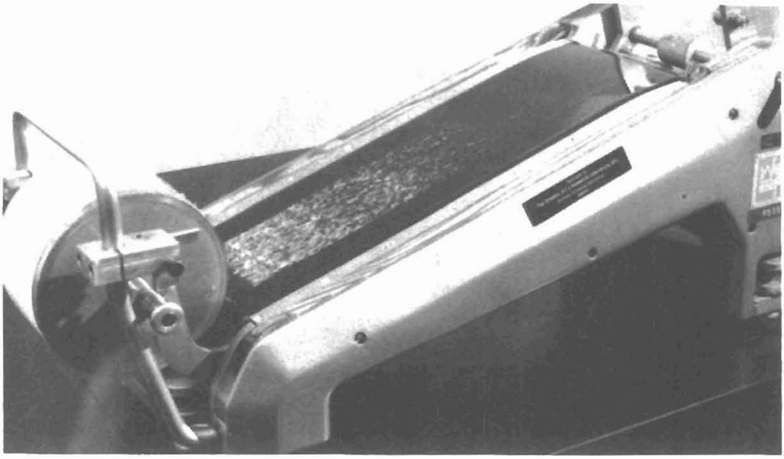

Figure 15. The GFL inclined plane.

The Varkaus method

The GFL rotary letterpress tester (Figure 16) is used in the Varkaus or Kuvaja [72] method. The method is based on ink transfer mass balance. In a regular printing operation, ink is transferred from the inked printing plate to the paper substrate. In theory, there should be no transfer of fines or fibers from the paper back to the printing plate, so the mass balance of the printing operation is positive in favor of the paper. In practice, some fibrous material is pulled from the paper surface, and ends up on the printing plate, depending on both ink tack and overall paper surface strength. By the correct choice of ink, the mass balance can be made either positive or negative. In other words, a greater weight of fibrous material may be transferred to the printing plate than the weight of ink transferred to the paper.

In the routine Varkaus test, prints are made according to SCAN-P35:72 [100], at 4.6 m/s and 15 kN/m, but with an IPI tack-graded ink No. 3. The average mass balance of 5 prints, made at 5 g/m^2 of ink on the plate, is reported as the paper surface strength. The more negative the value, the poorer the paper surface strength, and the more positive the value, the better the paper surface strength. It should be noted that in the routine Varkaus test, twin-wire papers tend to delaminate.

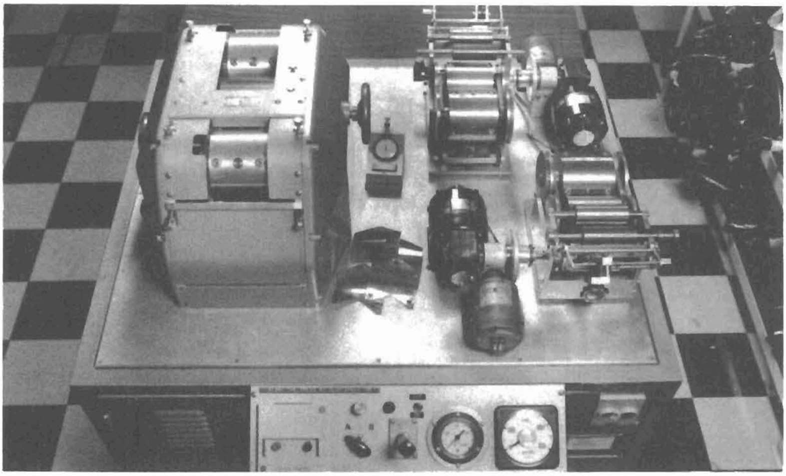

Figure 16. Both the Elphick (IPC) [102] and the Kuvajaa (Varkaus) [72] methods are performed on such a GFL rotary letterpress tester [100]. The tests are more common in England, and Scandinavia, respectively.

In the complete Varkaus method, 8 prints, each inked at 5 g/m^2 on the printing plate, are made with printing speeds ranging from 0.73 m/s to 5.84 m/s. The slope of the curves (Figure 17) is an indication of overall paper surface strength. The steeper the slope, the poorer the paper. The prints can also be visually ranked for surface deterioration. The weight of fibrous material removed from the paper surface has not been reported. Karttunen et al [11,81,82] have adapted the Varkaus method to the IGT pick tester. In his lint study performed on 17 newsprints, Karttunen found weak correlations (R_2 below 0.50) between the IGT-Varkaus test (top and bottom sides of paper), the routine Varkaus test (top side only), and linting on a Goss Community web offset press [81]. Delamination of weak newsprint significantly reduced the regression coefficient between the Varkaus test and commercial offset linting when testing papers on the bottom side.

The TFL method

In the TFL method proposed by Larsson [16], the printing nip consists of an upper rubber roll, inked with a poly(isobutene) oil, and a lower metal roll driven by a motor (Figure 18). The particles are collected from the

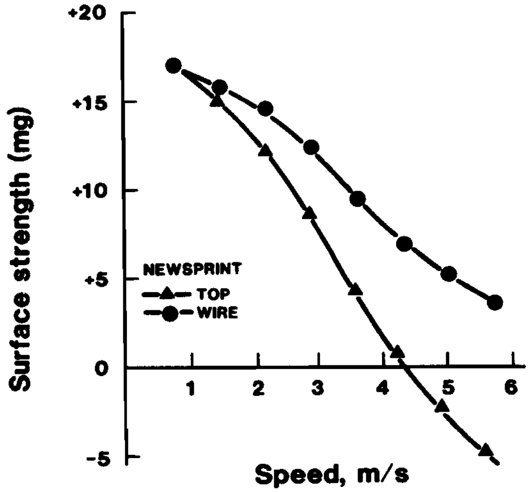

Figure 17. The Varkaus surface strenght as a function of printing speed [72]. The shape of the curves describes the overall ink transfer and surface strength of the paper.

rubber roller by means of an adhesive tape. A magnifying projector (100X) is used to count and record the particle length. The pulling forces responsible for the particle removal from the paper surface are function of the printing conditions and are adjusted by varying printing speed, pressure, and poly(isobutene) film thickness. Larsson found that the total number of longer fibrous particles would increase as a function of the printing speed, and as a function of the thickness of the poly(isobutene) layer. He concluded from these observations that changes in the printing conditions of a commercial offset press would not only change the weight but also the length characteristics of the lint accumulated on the offset blanket. However, the effects of ink film thicknesses could not be confirmed on the full-scale test when ink-feed was varied within practical limits.

The IGT fluff test

The IGT fluff tester [99,101] consists of a roller (Figure 19) inked with a poly(isobutene) oil that is slowly rolled by hand onto 25 sheets of paper. The roller can be mounted on the IGT printability tester and printed onto a reference surface so that a permanent or "hard" copy of the dust deposits can be made. The prints are compared to a set of standards arbitrarily ranging from 1 to 6 as a

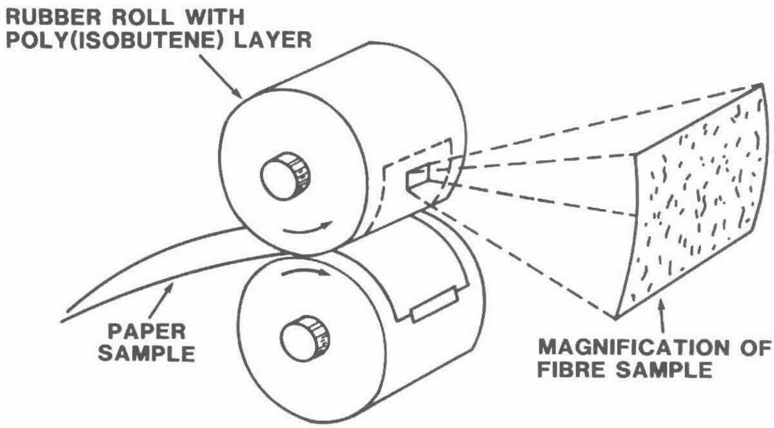

Figure 18. The TFL method [16] is used at the Swedish Newsprint Research Centre to evaluate the linting propensity of paper as a lint count. Fiber length can be measured.

function of the dust contamination. Although no correlation was ever shown with commercial offset linting, the test is commonly used in Dutch printing pressrooms to accept or reject a batch of paper [99].

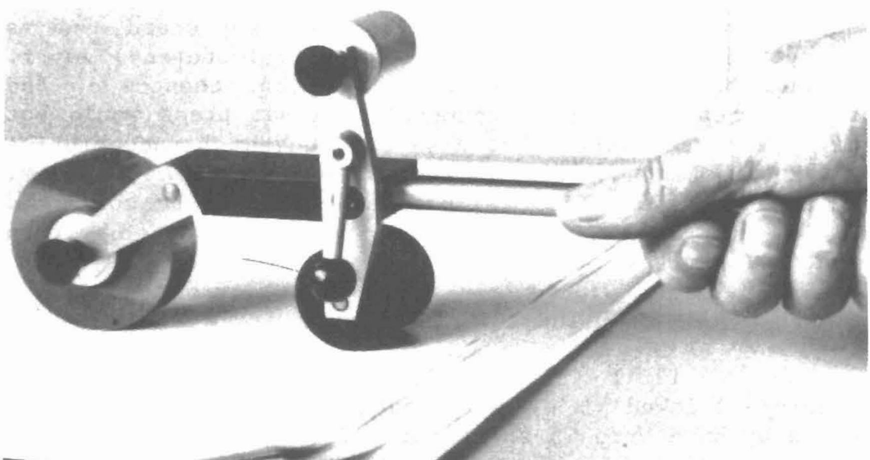

Figure 19. The IGT fluff tester [101] being rolled on a paper sample.

The wet-pick tests

In the offset process water is applied to the paper surface both in image and in non-image areas. In wet-pick tests water is applied to the sheet before the pick test in order to duplicate the offset dampening.

The most common wet-pick test is the IGT wet-pick [83], where a special attachment is provided (Figure 20) to pre-dampen the sheet before printing. Dampening is performed at constant speed (1 m/s). The pick test is then performed, as usual, in the accelerated mode. As the reproducibility of the IGT wet-pick was found to be strongly dependent on the ability to maintain a constant ($\pm$ 0.1 μm) water film thickness, Karttunen proposed a technique [84] based on water condensation. He showed that an even and reproducible 0.9 μm water film condensed at the printing disc surface when the disc was taken from a cold environment (4°C) to the conditioned atmosphere of the laboratory. He also cautioned against the influence of ink repellence caused by the presence of water on the paper surface that could prevent picking. The wet paper surface would then appear to be stronger than the dry one as the wet-pick value would be artificially increased by the ink repellence phenomenon.

Figure 20. The IGT printability tester [99] set up for a wet-pick test. The film of water is applied to the paper at constant speed with the upper rubber roller. The pick test is then performed in the accelerated mode.

In the "wet" adaptation to the LTF pick tester [89], the inked piece of blanket is replaced by a special attachment containing both the regular inked blanket and a dampening blanket. The dampening blanket consists of a smooth wet filter paper. To obtain a water film thickness comparable to that found in offset printing, the filter paper is wetted with 0.05 mL of water, and the excess water is blotted off by a fixed number of layers of absorbent tissues. The moisture level can be adjusted as a function of the number of tissue layers used. The test is first performed with the "dampening blanket" in place, and then with the inked blanket in place. All steps of the procedure are timed. As in the dry test, the evaluation of paper surface failure is done by visually comparing the test prints to previously established standards.

Karttunen [81] tried the Varkaus test with premoistening of the sample. However, the results were comparable to the dry Varkaus test results, and the test was not further developed.

Printing and rubbing tests

In the IPC or Elphick method [15,102] a dry offset solid print is produced on the GFL rotary letterpress tester (Figure 16). The freshly printed paper surface is then abraded with the PIRA rub tester (Figure 5), and fibers removed by the rubbing are counted.

To reproduce the inked blanket-paper contact of an offset press, the GFL rotary letterpress tester blanket is inked with GFL standard ink [100]. An even inking of the blanket is obtained by printing (5.9 m/s, 0.25 MPa) 6 successive times from the inked plate (4.6 g/m^2) to the blanket. The paper is then printed at 0.7 m/s, with the inked blanket acting as a printing plate. Fifteen minutes after printing, the printed sample is abraded for 50 revolutions at low pressure (3.5 kPa or 0.5 psi) with the PIRA rub tester against the corresponding side of the unprinted paper (printed top to unprinted top, and printed bottom to unprinted bottom).

Fibers removed from the rubbing action leave white uninked areas on the print. The rubbed print is analyzed under a binocular microscope fitted with an ocular containing a grid of five parallel lines which covers 1 cm^2 of the sample. Only white areas crossing one grid line are counted. The lint count is reported as the average of machine and cross machine direction count. In a slightly modified version of the Elphick lint count [103], five counts are made in the machine direction and five in the cross machine direction. The lint count is reported as the overall average.

According to Elphick [15], who found a good correlation between the lint count and commercial offset linting, a lint count less than 32 fibers per cm^2 is necessary to give acceptable offset press performance. However, Karttunen [11] found no correlation between the Elphick lint count and commercial offset linting (even worse, the lowest lint value according to the Elphick lint count gave the highest lint weights on the full-scale run). The Elphick lint count is also tedious to perform, and is not applicable to routine evaluation of paper linting propensity.

EVALUATION OF PULP LINTING PROPENSITY

Considering that the external surface of cellulose fibers directly involved in interfiber bonding depends on the pulp specific surface [104], Wood and Karnis [19] developed the Pulp Linting Propensity Index (PLPI), defined as the weight fraction of a pulp having fiber length less than 1 mm and specific surface less than 2.5 m^2/g. In this test, a hydrocyclone is used to separate the fines or fibers according to their specific surface areas. Owing to their lower drag coefficient, particles of low specific surface settle faster than particles with high specific surface. The testing conditions used to measure the PLPI are listed in Table II.

TABLE II - HYDROCYCLONE PLPI TESTING CONDITIONS [20]

Hydrocyclone diameter:	51 mm (2-inch)
Tip size:	
First pass:	7.9 mm (10/32 inch)
Second pass:	7.9 mm (10/32 inch)
Third pass:	4.0 mm (5/32 inch)
Fourth pass:	4.0 mm (5/32 inch)
Feed Consistency (All stages)	0.15%
Pressure Drop:	2.4 atm (20 psig)
Sample size:	160 g to 200 g

Although only a very small fraction (about 1 in 7,500 to 75,000 particles) of the low specific surface area fibrous material actually becomes lint, the authors found that the linting propensity of paper manufactured on a given paper machine increased with increasing PLPI. Paper linting was determined using a laboratory web-offset press [105]. However, for a given PLPI, different paper machines produced different lint counts in the web offset printing test.

The PLPI, although quite tedious and difficult to perform, is the only test evaluating the linting propensity of pulp. It allows the contributions of pulp variables to the linting propensity of paper to be separated from the papermaking variables, and is best suited to developmental work.

OFFSET PRINTING TESTS

The first offset press was patented in 1875, about 80 years after the invention of lithography by Senefelder [106]. Coupe [107] was the first to suggest the use of an offset press to evaluate the linting propensity of paper. In 1958, Pritchard [108] was the first to report the use of a small offset press, to measure the linting tendency of papers containing esparto.

Three levels of offset press testing should be considered, depending on the test objective and/or the paper company goals: laboratory, pilot, and commercial scale.

The most commonly used laboratory presses, aside from the Apollo web-offset press, are small sheet-fed office-duplicator offset presses. These small office presses are inexpensive but their correlation with commercial web offset press linting has never been firmly established [21, 99]. However, the presses are useful for routine testing, and the printing conditions reproduce those existing on the sheet-fed offset presses used to print fine papers.

The pilot scale linting evaluation of paper requires a full width or half width (half-web in printers terminology) web-offset press with a significant amount of controls to ensure repeatability over a long period. Pilot press testing requiring large capital expenditure and long term company commitment, the approach is well suited to fundamental research and development of new products. The evaluation of paper linting propensity using the pilot press testing approach is now almost exclusively used by research centres as the Finnish Graphic Arts Laboratory (VTT/GTL) [109], and Paprican [110].

Commercial printing runs have also been used to evaluate linting propensity. However, the papermaker has very little control over the actual testing conditions. Due to the influence of ink-water balance on both print quality and linting, the repeatability of commercial offset lint tests is very poor, often greater than ± 60%. As a consequence, full-scale lint tests cannot easily be intercorrelated. Furthermore, disregarding the fact that bench tests do not duplicate commercial offset printing, the poor repeatability and reproducibility of commercial offset lint evaluation would prevent a high level of correlation between bench scale and commercial linting evaluation.

Sheet-fed offset printing

The most common office sheet-fed offset presses used to evaluate linting are the Rotaprint 40/80 [21,111], the AB Dick [112,113], the Solna 124 [14], and the Versatec [18]. Other offset presses used to evaluate linting are the Lithomaster, Kora, Heidelberg, and Multilith duplicators [18,33]. Usually, a fixed number of impressions - ranging from 100 [21,111-113] to 2,000 [18] - are printed. Printing may be done either under fixed printing conditions [21,111], or under conditions to optimize print quality for a given paper [18]. The press speeds range from about 4,000 impressions per hour to 6,000 impressions per hour, in the low end of the commercial range for most duplicators.

However, printing press parameters, such as blanket type or age, or the plate dampening properties have been shown to influence both print quality and the linting test results [25,114,115]. Unfortunately, the printing conditions are frequently not reported. Similarly, inks, fountain solutions, ink and fountain solution film thicknesses, print density, ink-water emulsification rates, printing pressures and/or dot gain, printing plate, press peripheral velocity, and press geometry are often not reported. It is therefore impossible to duplicate experiments, or even to compare results obtained on different presses. Based on work done at Paprican that will be reported in subsequent reports, it is also suggested here that apparently contradictory lint values could well be explained on the basis of unknown or unreported differences in printing conditions.

As no standard exists for the evaluation of lint particles accumulated on the offset blanket, various methods have been developed for the analysis of lint. The lint is analyzed in non-image areas, and/or solids (100% image area), and/or any halftone combination. The lint is sometimes evaluated directly on the offset blanket or is removed with an adhesive tape. Particles longer than a fixed length are counted (from 0.2 to 3.0 mm) or even weighed. The lint result can be reported as a lint weight, or a lint count, or a total particle length per 100 (or 1,000) copies and per unit of blanket surface. The adhesive tape with the lint can also be compared to "standards" and the linting propensity of paper is then reported as a scaled value ranging from 0 to 10 or from 0 to 100% of blanket covered by lint [116].

Web-offset printing: the Apollo lint test

Since the day-to-day variations in commercial presses are too large for developmental work, and small office sheet-fed presses use paper sheets whose edges may have loose fibers that can affect the lint test, Heintze et al [105] proposed a lint test method on a small web offset press. The test, now commonly used in the Canadian pulp and paper industry, is known as the Apollo lint test.

Five hundred copies are printed on an Apollo A-135 web offset press at 300 fpm (1.52 m/s) with printing pressure set to give a "sharp dot". A yellow ink of medium tack (11 on the LTF Inkometer at 800 rpm and 90°F) and an acidic (pH = 4.6) fountain solution are used to obtain a solid print density in the range 0.52 to 0.55 (on a MacBeth densitometer). At the end of the press run, lint is removed from the blanket with an adhesive tape. All particles longer than 1/32 inch (0.8 mm) are counted in a total of 16 areas. These 16 areas include 4 blanks, or non-image areas, 4 solids, and 8 halftones of 85 lines per inch screen at 36% and 70% dot area.

A minimum of 2,000 impressions is made to bring the ink-water emulsification to a steady state. Five hundred copies from a reference paper roll are then printed. The reference roll test is repeated at the end of a daily series of lint tests. The ratio of the "standard" count from the reference roll to the day's result of the reference roll serves as a correction factor for a given day of test results. Although the use of reference test rolls to account for the variations in the press conditions has been mentioned at various meetings [33,99, 116], it is the first time that they were included as part of the test.

Although no data were reported, Heintze et al stated that the test gave a good correlation with pressroom performance. A lint count of less than 30 per cm^2 is supposed to indicate acceptable pressroom performance. It should however be noted that the test requires time and know-how to perform (hiring a pressman being the most sensible solution), and therefore is also better suited to developmental work than to routine linting evaluation.

SUMMARY

Although a large variety of tests exist to evaluate paper offset linting propensity, it has been shown that all lint tests suffer from deficiencies that prevent any direct interpretation of the test results as far as changes in the papermaking or pulping processes are concerned. Non-offset tests suffer from oversimplification, and true-offset laboratory tests suffer from the difficulty in evaluating the test results in papermaking terms.

The non-offset printing tests have been considered as force generators, and have therefore been sub-divided according to the level of the force acting on the paper surface. The forces generated in the various bench tests range from the soft action of a vacuum or a cloth to the hard pulling action of the pick or Varkaus tests that can cause complete delamination of the paper structure. Therefore, the surface defects that are related to fibrous material removal in offset printing have been differentiated as a function of the severity of the paper structure deterioration. In order of severity, the main paper surface defects are dusting, linting, picking, and delamination.

It is apparent from this review that all non-offset methods evaluate either picking and/or dusting but not the true linting propensity. However, the tests are simple, repeatable, inexpensive, and can be used when severe linting differences exist among samples. The level of correlation between non-offset tests and full-scale printing was found to be quite poor, with most regression coefficients below 0.50.

Although the true offset laboratory printing tests evaluate the linting propensity of paper, their usefulness is hindered by several factors. Sheet- or web-fed offset presses are complex, and the tests are expensive to perform on a routine basis. Owing to the complexity of the offset process, the true-offset tests require specially trained personnel. Further, the repeatability of these offset printing tests is usually quite poor, and it is difficult to relate the test results to subtle changes in the pulping or papermaking processes. However, the use of reference paper rolls and adhering to a strict printing procedure are good means to achieve test repeatability.

In conclusion, although many tests for evaluating paper surface strength defects are at the papermaker's disposal, the simple test that could be used to relate paper linting propensity to both pulp and paper properties has still not been designed. Since no consensus appears to exist as far as linting mechanisms are concerned, it is also suggested that such a test will not be developed before a thorough understanding and modelling of the principles involved in lint material removal from the paper surface has been achieved.

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APPENDIX

ACRONYMS

GATF	Graphic Arts Technical Foundation, U.S.A.
GFL	The Graphic Arts Research Laboratory, Sweden (Grafiska ForskningLaboratoriet i Sverige).
IGT	Research Institute for Printing and Allied Industries (Instituut voor Grafische Techniek), now Reprotest BV, Holland.
IPC	Institute of Paper Chemistry, U.S.A.
IPI	International Printing Ink Co., Inmont Corp., U.S.A.
LTF	Lithographic Technical Foundation, now GATF, U.S.A.
PATRA	Printing, Packaging and Allied Trade Research Association, now PIRA, England.
PIRA	The Research Association for the Paper and Board, Printing and Packaging Industries, England.
SPPP	The French Newspaper Association for Paper Joint Purchase (Société Professionnelle des Papiers de Presse), France.
TFL	Swedish Newsprint Research Centre (Tidningspappersbrukens ForkningLaboratorium), Sweden.
VTT/GTL	Technical Research Centre of Finland Graphic Arts Laboratory, TRCF (Valtion teknillinen tutkimuskeskus, VTT Graafinen laboratorio).