5-1956

Impartial Evaluations of the Printing Quality of Paper

Warren R. Engel
Western Michigan University

IMPARTIAL EVALUATIONS OF THE PRINTING QUALITY OF PAPER

A

DISSERTATION

SUBMITTED TO THE FACULTY

OF

WESTERN MICHIGAN COLLEGE

BY

WARREN R. ENGEL

IN PARTIAL FULFILLMENT OF THE PREREQUISITES

FOR THE DEGREE

OF

BACHELOR OF ARTS

MAY 29, 1956 KALAMAZOO, MICHIGAN

ACKNOWLEDGMENT

The writer wishes to express his sincere appreciation to Dr. Robert A. Diehm for his advice and assistance. I would also like to thank the Michigan Paper Company, Allied Paper Mills Inc., E.J. Kelly Company, and Sinclair and Valentine Company for making papers and inks available to me.

ABSTRACT

Several methods for the evaluation of paper have been investigated for their desirability as means of an impartial evaluation of the printing quality of paper. The halftone plate method showed the most desired results as an impartial evaluation of both coated and uncoated papers. The printing gage was not found to be a satisfactory method of evaluation. The drawdown method is especially significant in evaluating properties which influence the printing quality but lacks a suitable numerical evaluation.

TABLE OF CONTENTS

	Page
Acknowledgment........................	1
Abstract..............................	2
Literature Survey.....................	4
Literature Cited......................	11
Experimental Work.....................	12
Experimental Results..................	17
Conclusions...........................	19

IMPARTIAL EVALUATIONS OF THE PRINTING QUALITY OF PAPER

Literature Survey

HISTORICAL

Over the years the graphic arts and paper industries have made great technological and physical progress. However, the progress in finding a suitable method for evaluating the printing quality of paper has not kept pace with that of the rest of the industry. This lack of progress has been due partly to the complexity of the printing operation, lack of a suitable definition (1), and the lack of an adequate instrument or combination of instruments to measure this quality (2).

It is surprising to learn that inspite of the fact that over 90 per cent of the paper manufactured is meant to be printed, there has been a very small proportion of the technical literature available devoted to the technical problems connected with the printing quality of paper until the last decade.

PRINTING QUALITY

The printing quality and printability of paper are of vital importance to both the printer and paper maker due to the fact that little can be done to alter these qualities of the finished sheet. The printer can adjust the inks and press within limits, but beyond these, the paper is useless and must be discarded. An accurate definition for such a vital property is very difficult to find. Printing quality has been evaluated by many individuals who have been at a loss to define it in a few words. Reed (4) states that "Print Quality is defined as the general appeal or attractiveness of the printed reproduction to the viewer." Zettlemoyer and others (5) suggest that "Print Quality is the aggregate effect of the various appearance characteristics of printed matter." Commonly used factors used in evaluating this quality are the finish and contrast of printed and unprinted areas, uniformity of solid and halftone areas, print through and legibility.

PRINTABILITY

Printability of paper is not the principal subject in this survey, but deserves mention due to the fact that it too is a rather difficult quality of paper to define. It is often confused with printing quality and evaluated by several of the same basic methods. Reed (4) defines it as "...the combined properties and condition of paper that affect its press performance." Andella (6) describes the property "as that quality in paper that lends itself well to faithful reproduction by possessing the necessary affinity to accept an ink from a printing plate and properly hold the full color tone values of the halftone dot structure." Kantrowitz (7) arranges the tests for evaluating this property into three groups.

1. Physical tests for determining durability.
2. Chemical tests for evaluating permanence.
3. Tests for evaluating the printing properties.

In general, the related properties are strength, smoothness, ink receptivity and pick strength.

METHODS OF EVALUATION

Initial Work - Realizing the most important test the paper will undergo is the printing process, P. H. Prior in 1934 pointed out that the performance of paper in the printing press could be predicted with the use of a hand operated proof press, standard ink, ink film and printing pressure. Bekk developed the techniques further and measured the blackness of the resulting print by means of a reflection meter (3). Laroque (1) investigated the method further with emphasis placed upon the printing pressure and its effects upon the finished sheet. He found that smoothness is the most important single factor in determining the satisfactory transfer of ink to a sheet having good uniformity of appearance in the printed solids and in the halftones. He has found that softness is of secondary influence in modifying the printing quality of the sheet. He feels that the product of the smoothness and softness tests presents a better picture of the printing operation since existing smoothness measurements are not obtained in the range of pressures exerted in this operation. This product correlates well with the numerical determination of printing quality obtained by counting the number of missing dots in a given area of the printed surface.

Berberich and co-workers (8), using the method described by Weymouth (2) for the use of a Vandercook No. 4 proof press, carried out extensive experiments on halftone reproduction. However, this method depended upon the opinion of several qualified observers.

Recent Developments - In order to obtain an impartial numerical evaluation of the printed sheet, recent investigators have been interested primarily in the printed, unprinted, solid and halftone areas of the test sheets printed on a proof press.

In general the properties investigated by most investigators are color, gloss, uniformity, sharpness of outline, print-through, tone value and contrast (10).

Numerical evaluation of the solid print has been studied by Bekk (3), and Buchdahl and co-workers (9) who choose a rather tedious photographic-density method of evaluating the uniformity of the print.

They were also interested in the halftone evaluation. This experiment was based on the assumption that the tone values of the print should correspond to those of the plate. Using a plate consisting of halftone blocks and solid areas and a picture for subjective evaluation, they plotted the actual tone densities of the print, measured by a spectrophotometric brightness method against the Densities predicted by the plate. This method is rather tedious but the results correspond well with the subjective evaluation. He suggests that this test be incorporated with several others to obtain a true numerical value.

Laroque and co-workers (3) suggest that when a numerical value of the printing quality of news print is required, reflectance measurements be made over the entire printed area in order to obtain the average reflectance, R. During these measurements the printed sample is backed by several unprinted sheets of the same paper. The original reflectance value, R. is corrected to a specified amount of ink on the printed sheet. The third step is to divid this corrected value, $R_{corr.}$ by the brightness or reflectance of the unprinted paper, R_{paper}. The values so obtained will lie in the range of from 15 to 40 per-cent reflectance, the lower values denoting the better quality. In order to obtain a quality scale in which the higher values represent the better paper the resulting figure is subtracted from 100. This is the value Bekk called the "printing blackness" and which they recommend as a designation of printing quality.

$$\% \text{ Printing Quality} = 100 - \frac{R \text{ corr} \times 100}{R \text{ paper}}$$

Diehm (11) suggests that a plate containing halftone blocks of different line screen and per cent coverage should be used in the determination of this quality. Analysis of ink coverage is made by a brightness tester. The halftone pattern is analyzed and numerically ranked for "printing fidelity" by the use of a bond lens. The three factors involved in this test are:

1. Presence of absence of dots.
2. Dot size
3. Dot irregularities.

"These operations permit a new definition of printing quality based on ink coverage and print fidelity. Printing quality is the per cent ink coverage obtainable in perfect print fidelity. It is expressed numerically by:

$$P.Q. = \frac{\text{Ink Coverage} \times \text{Print Fidelity}}{96} \times 100$$

This test is simple and can be performed rapidly in the laboratory equipped with a proof press. It is recognized that this test should be supplemented by tests relating to the desired physical and chemical properties of the paper."

Connell (12) uses a National Printing Ink Research Institute Grindometer as an instrument for measuring the printing properties of paper. While this "gage" is used primarily to evaluate the ink setting time and picking of paper, it could also be used to obtain numerical as well as visual values of printing quality.

Hull and Rogers (13) suggest the use of a drawdown technique under simulated printing pressure in which the paper is characterized as it would appear during the printing operation.

These procedures of evaluation are not the complete answer to the problem but are a step in the right direction towards a goal of a satisfactory and universally accepted test of the printing quality of paper.

Literature Cited

1. Larocque, G.L., "Laboratory Methods for Measuring the Printing Qualities of Paper", Pulp & Paper Magazine of Canada, 39, no. 2:99-105 (1938)

2. Weymouth, F.A., "Testing the Printability of Paper with Ink, "Technical Assoc. Papers, Series 25:247(1942)

3. Larocque, G.L., Axelrod,B., and Clark,S., "Measuring the Printing Quality of Newsprint", Pulp & Paper Magazine of Canada, 52, no. 3:166 (1951)

4. Reed,R.F., "Coated Paper Properties and Their Relation to Printability and Print Quality in Lithography", Tappi 38, no. 11:648 (1955)

5. Zettlemoyer,A.C., Fetsko,J.M., and Walker,W.C., "Printing Ink-Paper Relationships II, Numerical Evaluation of Letter Press Print and Printing Quality", Tappi 36, no. 2:161-9A (1953)

6. Andella,D.J., "Evaluation and Analysis of Printing Results", Paper Trade J. 128, no. 4:23 (Jan. 27, 1949)

7. Kantrowitz,M.S., "Paper Testing in Relationship to End Use", Paper Trade J. 128, no. 25:84 (1949)

8. Berberich,O.P., Englehart,L.F., and Zucker,M., "Testing Printability of Paper with Ink II", Technical Assoc. Papers, Series 31:281 (1948)

9. Buchdahl,R., Polglase,M.F., and Schwalbe, H.C., "The Measurement of Tone Reproduction of Half-Tone Prints and Uniformity of Solid Prints", Paper Trade J. 122, no. 18:41 (1946)

10. Fetsko,J.M., "Printing Ink-Paper Relationships III - Critical Literature Survey", NPIRI Project Report No. 23, (1952)

11. Diehm, R.A., "The Elimination of the Human Element in the Determination of Printing Quality", Tappi 33, no. 2:47-9A (1950)

12. Connell, H.J., "The Printing Gage", Tappi 38, no. 8:460 (1955)

13. Hull, H.H., and Rogers, M.C., "New Methods for Observing Properties of Paper which Influence Printability", Tappi 38, no. 8:468 (1955)

EXPERIMENTAL WORK

After studying the literature for suitable methods for the impartial evaluation of the printing quality of paper by some form of the printing operation, it was decided to concentrate my efforts upon three suggested methods. They are:

1. Proof Press and Halftone Plate Method.
2. "Printing Gage" Method.
3. Drawdown Technique.

Both coated and uncoated papers were obtained for use in these evaluations as was a sufficient supply of a standard ink for use in the proof press work.

Proof Press and Halftone Plate Method.

The basic theory behind this evaluation is that good printing quality is obtained when "sufficient amounts of ink are applied to give tone gradations without altering the halftone screen pattern."(11)

In this test the paper is made the variable while the press and ink are held constant. A halftone plate showing six tones in each of five screens was used on a Vandercook #4 Proof Press. The ink was a heavy bodied, #1 H.T. Black letter press ink.

After becoming familiar with the press and considerable makeready time the papers were printed under standard conditions of temperature for the ink, press and paper. All press and inking operations were held constant so that the only variation in the printing operation could exist in the paper itself. Three cc. of ink were added to start with an ink volumeter and an additional cc. was added after printing eight sheets.

The halftone screens on this plate cover the range of printing from newsprint at 85 lines to fine coated papers at 133 lines. The tones range anywhere from a highlight to a solid print.

The print was then evaluated for ink coverage by determining the average brightness of the 10% and 90% tones. The ink coverage (I.C.) is calculated by:

$$I.C. = \frac{B10 - B90}{BP} \times 100$$

where: B10 = the brightness of the 10% tone.
B90 = the brightness of the 90% tone.
BP = the brightness of the paper.

The perfect print will have an ink coverage of 80% (i.e., difference between 10% and 90% tones.)

Next the print is evaluated for printing fidelity by means of a hand lens since screen pattern is also vitally important. Each tone is evaluated for the presence or absence of dots, size and uniformity, and unbroken and undistorted dot outlines. A perfect tone will have a value of two for each of these evaluations. When only a few defects are present a value of one; and when more than 25% of the dots show a defect a value of zero. Therefore each tone has a possible value of six and the entire print a value of 120 for perfect printing fidelity (Used only the 90, 70, 50, and 10% tones for evaluation).

These evaluations permit printing quality to be expressed as the percent ink coverage obtainable in perfect print fidelity and is expressed numerically as:

$$P.Q. = \frac{I.C. \times P.F.}{96} \times 100$$

Where: P.Q. = Printing Quality
I.C. = Ink Coverage
P.F. = Printing Fidelity
96 = Constant (percent ink coverage in perfect fidelity in 100% printing quality.)

The Printing Gage.

The Printing Gage is simply the National Printing Ink Research Institute Grindometer, used for measuring the fineness of grind of printing inks, fit into the bed of the Vandercook #4 Proof Press. The gage is a type high metal block containing two six by one inch grooves machined into the top. These grooves vary in depth from zero to 1/1000 of an inch, like an inclined plane. Along the side of each groove are a series of marks (ten in all) indicating the depth in tenths of 1/1000 of an inch. The gage is inked at the shallow end with the standard heavy bodied #1 H.T. Black ink and the grooves filled with the scraper blade.

After inking the gage, an impression was made on the paper to be tested and after 60 seconds a transfer is made unto a standard coated test paper. This transfer along with the original impression were then to be evaluated numerically for printing quality by means of the depth marks along the side of each groove.

The Drawdown Technique.

This method is very rapid and easy to use since it requires a minimum amount of equipment. The testing procedure is divided into three parts.

1. The rigid blade drawdown which is used to show the caliper and formation of the sheet.

2. The flexible blade drawdown is used to characterize the coating surface.

3. The wipe test which shows the fine character of the coating surface.

The Rigid Blade Drawdown.

Equipment:

1. The rigid blade used in this test is the scraper blade from the NPIRI Grindometer. It is straight but dull and has been ground to close tolerances.

2. The blade is held in a laminated plastic block. This block has a pin which serves to center the weights over the blade. An adjustable screw is provided so that the proper blade angle may be maintained. The weight of the blade and holder is 1580 gram.

3. A heavy sheet of plate glass is used as a test support.

4. The ink is a specially formulated polybutene base pigmented ink (black).

Method:

The glass and blade are tested by drawing the blade over a small amount of ink on the glass and observing the deposit. If the deposit is uniform the blade and glass are true and are suitable for testing purposes. The paper is then tested diagonally to machine direction so that marks both parallel and cross direction to the machine may be emphasized. A four and one half kilogram weight was used in this test. The blade was moved at a rate of ten inches per three seconds.

The Flexible Blade Drawdown.

Equipment:

The flexible blade used in this test is a section of a .0005 inch "gravure doctor blade" and is used in the same holder with the same ink.

Method:

Five sheets of news print were placed on the plate glass and the paper sample to be tested on it. A one kilogram weight centered in the middle of the holder was used. The blade was moved at a rate of one inch per second.

The Wipe Test.

A polybutene ink containing a soluble red dye was used for this test. The ink was spread on the paper sample and allowed to remain for fifteen seconds after which it was removed by the rigid blade and wiped dry with a cloth.

RESULTS

The results obtained by evaluating the papers printed in each of the described methods are:

<u>Halftone Plate Method</u>

Sample Number		Ink Coverage	Printing Quality
1. Mirror Gloss C2S Enamel	80#	76%-74%	86%-81%
2. H.F. Firmfold C2S Enamel	70#	75%-73%	84%-81%
3. Monarch Litho C1S	70#	72%-74%	75%-77%
4. #2 C2S Enamel	70#	73%-71%	75%-75%
5. Flexible Enamel C2S	70#	78%-76%	80%-82%
6. Hd. Szd. Writing	16#	53%-54%	31%-38%
7. Hd. Szd. Tablet	16#	50%-50%	34%-34%
8. Coronia E.F.	45#	57%-58%	49%-53%
9. Wolverine Offset	45#	49%-44%	24%-28%
10. Test Offset	45#	53%-64%	34%-38%
11. Test E.F.	45#	55%-57%	34%-36%
12. Plainwell Bond	16#	46%-46%	17%-20%
13. Mongomery Duplicator	20#	54%-55%	39%-42%
14. Spruce Falls Newsprint		59%-59%	34%-34%

Printing Gage Method

Sample Number		Visual evaluation of transfer at step 4. % of surface free from ink transfer.
1. Mirror Gloss C2S Enamel	80#	Standard
2. H.F. Firmfold C2S Enamel	70#	80%
3. Monarch Litho C1S	70#	50%
4. #2 C2S Enamel	70#	80%
5. Flexible Enamel C2S	70#	85%

No significant results were obtained for the uncoated papers.

Drawdown Method

Sample Number		Visual evaluation, % uniformity of print.		
		Rigid Blade	Flex. Blade	Wipe Test
1. Mirror Gloss C2S Enamel	80#	50%	65%	70%
2. H.F. Firmfold C2S Enamel	70#	45%	55%	65%
3. Monarch Litho C1S	70#	40%	40%	-
4. #2 C2S Enamel	70#	45%	40%	60%
5. Flexible Enamel C2S	70#	45%	55%	65%

No significant results were obtained for the uncoated papers.

CONCLUSIONS

The experimental results show very clearly that the halftone plate method of evaluation gives the most significant results in a numerical evaluation of the printing quality. This test works well on either coated or uncoated papers and is reproducable within a range of five percent.

The "printing gage" method did not prove to be a satisfactory method for a numerical evaluation. The transfer sheets showed no significant difference from one sample paper to the next (coated or uncoated). Brightness measurements were used without success in an attempt to obtain a numerical evaluation.

The drawdown methods showed very significant results in the evaluation of coated papers and also were of some interest in the case of uncoated papers. However, this method lacks a suitable means of obtaining a numerical evaluation. Visual evaluation of the drawdowns permits one to estimate the quality numerically but is far from satisfactory.

Summary: 1. The halftone plate method is the best way to evaluate the printing quality of any paper. However, the amount of equipment and time required does not make it the most desirable for a control test.

2. The "printing gage" from the results of my study is of little use for the evaluation of printing quality.

3. For speed and a minimum of equipment the drawdown method is very desirable for use in evaluating coated papers. However the lack of a suitable numerical value would make it a good test to run in conjunction with the halftone plate method since it permits visual evaluation of several important properties.

May 29, 1956

Warren R. Engel