



6-1989

Design Specifications and Requirements of Paper for Flexographic Printing

Martha L. Stankey
Western Michigan University

Follow this and additional works at: <https://scholarworks.wmich.edu/engineer-senior-theses>



Part of the Wood Science and Pulp, Paper Technology Commons

Recommended Citation

Stankey, Martha L., "Design Specifications and Requirements of Paper for Flexographic Printing" (1989).
Paper Engineering Senior Theses. 515.
<https://scholarworks.wmich.edu/engineer-senior-theses/515>

This Dissertation/Thesis is brought to you for free and open access by the Chemical and Paper Engineering at ScholarWorks at WMU. It has been accepted for inclusion in Paper Engineering Senior Theses by an authorized administrator of ScholarWorks at WMU. For more information, please contact wmu-scholarworks@wmich.edu.



**"DESIGN SPECIFICATIONS AND REQUIREMENTS
OF PAPER FOR FLEXOGRAPHIC PRINTING"**

Submitted by:

Martha L. Stankey

**A Thesis submitted
in partial fulfillment of
the course requirements for
The Bachelor of Science Degree**

**Western Michigan University
Kalamazoo, Michigan**

June, 1989

June, 1989

**"DESIGN SPECIFICATIONS AND REQUIREMENTS
OF PAPER FOR FLEXOGRAPHIC PRINTING"**

Submitted by:

Martha L. Stankey

**A Thesis submitted
in partial fulfillment of
the course requirements for
The Bachelor of Science Degree**

Western Michigan University

Kalamazoo, Michigan

June, 1989

TABLE OF CONTENTS

	Page
TABLE OF FIGURES	ii
LIST OF TABLES	iii
ABSTRACT	iv
INTRODUCTION	1
THEORETICAL DISCUSSION	3
The Printing Process	3
The Flexographic Press	3
Printing Qualities	4
Testing	6
EXPERIMENTAL PROCEDURES	7
Initial Set-Up	7
Laboratory Procedures	7
RESULTS	9
Testing Data	9
DISCUSSION OF RESULTS	11
Designing of Specifications	11
Comparison of Specifications	13
CONCLUSIONS/RECOMMENDATIONS	16
LITERATURE CITED	17
APPENDIX I	18
APPENDIX II	27

TABLE OF FIGURES

	Page
FIGURE 1: FLEXOGRAPHY PRESS	4

LIST OF TABLES

	Page
TABLE #1: DISTRIBUTION BY PROCESSES	2
TABLE #2: TEST RESULTS OF FLEXOGRAPHIC NEWSPRINT	9
TABLE #3: TEST RESULTS OF LITHOGRAPHIC NEWSPRINT	10
TABLE #4: DESIGNED FLEXOGRAPHIC NEWSPRINT PAPER SPECIFICATIONS	12
TABLE #5: DESIGNED LITHOGRAPHIC NEWSPRINT PAPER SPECIFICATIONS	12

ABSTRACT

Flexographic printing is a direct printing from the plate to the paper. This process has been growing during the last few years, especially in the newspaper area. One of the problems in the industry today, however, is the lack of good paper specifications for the flexographic printing process. The objective of this project was to gather samples of good flexographic newsprint, and to test them for paper properties in order to determine a set of paper specifications for flexographic newsprint. Also, lithographic (the predominant printing process in the newspaper industry) newsprint samples were gathered in order to compare between the flexographic specifications and a set of lithographic specifications.

These papers were tested and specifications were designed from the data, and comparisons were made between the two types of newsprints. The paper properties which seemed to differ the most between the lithographic newsprint and the flexographic newsprint, and appear to be the best judge of a good flexographic paper are: smoothness, brightness, opacity, and strength properties. Further work should be done in this area with more time and more equipment.

INTRODUCTION

The use of flexographic printing has grown in the past few years and is now a major printing process.

This project was designed to develop paper specifications for the paper which is used in flexographic printing. Flexography began as a printing process which was called "aniline" printing. It was given this name because the ink which was originally used for the printing was made mostly from aniline dyes. In 1952, after a vote taken by most of the aniline printing industry, the name was changed to "flexography" printing (now commonly termed "flexo").

This printing process was originally developed for the packaging industry, especially flexible packaging such as cellophane. It has grown since its beginning use in the flexible packaging, and is currently being used on paperboard and corrugated boxes, label release paper, and just recently in newsprint. It is predicted that in the near future flexography will be commonly used for printing newspaper inserts, low budget magazines, and even for feature publications; and that by 1990 flexography will be the dominant relief process, representing about 18 percent of all the printing production. This can be seen in Table #1. (1)

Table #1: Distribution by Process

Printing, Publishing, and Packaging			
(not including instant and in-plant printing)			

	1982	1985	1990

Letterpress	15%	12%	5%
Flexography	14	15	18
Lithography	44	46	47-43
Gravure	18	20	21-25
Screen Printing and Other Processes	6	7	9

This thesis project wished to further the developments which have occurred during the past few years - especially in the area of newsprint paper requirements for flexographic printing.

THEORETICAL DISCUSSION

THE PRINTING PROCESS

Flexography is a relief printing process (printing from a raised surface(2)) and is a branch of the letterpress area of printing. It is one of the least expensive and one of the simplest of all the printing processes. And, until recently, the quality of the printing was not considered suitable for many purposes.

The process uses rubber or photopolymer printing plates and water- or solvent-based inks. The recent use of these precision photopolymer printing plates has produced good quality printing, which correlates with the demand for good quality printing.

THE FLEXOGRAPHIC PRESS

In its simplest form, the flexographic printing press is made of four basic parts: 1) a fountain roll, 2) an ink transfer roll, 3) plate cylinder, and 4) impression cylinder. These are seen below in figure #1.(3)

The impression roll(H) is a smooth metal roll which is used to support the paper web(G) against the printing plate(F). The printing plate cylinder(E) is also made of smooth metal. It holds the plate and rotates it to collect ink and transfer the ink to the web. The ink transfer roll(D) is a smooth or

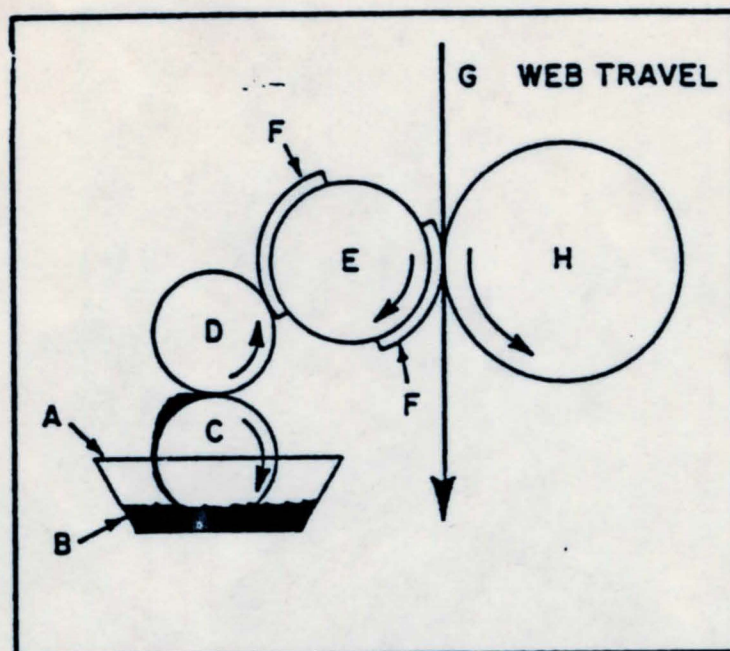


FIGURE 1

engraved, metal or rubber roll; and it transfers ink from the fountain roll to the plate. The fountain roll (C) is almost always a rubber roll which collects ink (B) from the ink fountain to give it to the transfer roll. The ink fountain (A) is a metal pan filled with ink that stays at a level touching the fountain roller; from there it will be transferred onto the rest of the press.

PRINTING QUALITIES

The special paper requirements for flexographic printing are very few, according to Bureau(4). The process is adaptable to a wide variety of papers and paperboards. These papers include: newsprint, coated offset paper, synthetic papers, and clay filled

paper and board. Flexography can print on more substrates than any other process. The advantages that have been seen in using flexographic printing for newsprint according to Rendulic(5) are:

- *No ink rub off with water based ink
- *Reduced start-up waste
- *Ability to print on lower basis weights
- *Environmentally safe with water-based inks
- *Consistent quality
- *Vibrant process color reproduction
- *Lower press operating costs
 - Fewer web breaks
 - Reduced utilities
 - Cleaner pressroom
 - Lower press maintenance

Many sources have suggested that the following properties are the most important when considering substrate for the flexographic process: smoothness, density, ink receptivity, uniform roll structure and sheet formation, low surface dust, good surface strength, and low water absorption rate (for water-based ink). These properties seem to correlate with the demands known for the flexo process; however, many of the demands of the flexo process are still to be determined.

Some of the problems which are seen during the printing process include: plate "fill-in" on the printing press which can be eliminated by decreasing the surface dust, print mottle which can be eliminated by decreasing the water absorption rate, show-through which can be eliminated by using water-base ink, and sheet uniformity which must be eliminated at the paper machine by careful observation of the paper web.

TESTING

In the printing process the tests which are commonly run on paper to determine its characteristics include the following:

- *Smoothness
- *Basis Weight
- *Tear
- *Burst
- *Ink Hold-Out/Absorption
- *Density/Bulk
- *Porosity

These tests help to determine whether the paper will perform well on the printing press, and also to determine the printing process with which it will work best. The tests above are also common to the flexography printing process.

EXPERIMENTAL PROCEDURES

INITIAL SET-UP

For the testing of the paper samples, various paper and printing companies were contacted, and samples of their flexographic printing newsprint paper were gathered. These samples contained newsprint which prints very well on flexographic printing presses. These samples were gathered from:

Great Northern Paper, Co.
The Chicago Tribune
The Portland Evening Express (courtesy of Motter Printing Press Co.)
Southeastern Commercial Printing, Corp. (for the Greater Buffalo Press)
Kruger, Inc.

Paper samples were also gathered of lithographic printing newsprint. These samples were gathered to use as a standard to compare to the flexographic specifications. These paper samples were supplied by:

The Kalamazoo Gazette
The Western Herald
Great Northern Paper, Co.

LABORATORY PROCEDURES

All of the newsprint samples were tested using the TAPPI standard paper testing methods; and those used are listed in the appendices. The following tests were performed:

*Smoothness
*Wax Pick
*Brightness

- *Opacity
- *Gloss
- *Basis Weight
- *Caliper
- *Density
- *Mullen (burst)
- *Tensile
- *Tear
- *Fold

These paper samples were also observed for general trends among the newsprints for the different printing processes, such as formation.

RESULTS

TESTING DATA

This test data has been analyzed statistically to determine the mean, the standard deviations, the variance, the median, and the mode of each procedure. These values are shown in Table #2 and Table #3 on the next page. This data is from the flexographic newsprint and the lithographic newsprint. Showing both sets of data allows for comparison between the two types of printing requirements. All of the raw data is also given, in the appendices.

Table #2: Paper Test Results For Flexo

Paper Property	mean	std.dev.	variance	median	mode
Brightness	58.44	1.21	1.46	58.57	58.57
Opacity	87.63	2.80	7.82	89.02	90.27
Smoothness (10 kgf/cm ²)	5.36	0.19	0.03	5.34	5.34
Smoothness (20 kgf/cm ²)	4.21	0.08	0.01	4.21	4.21
Gloss	10.31	1.18	1.39	11.11	11.11
Wax Pick	8.73	1.57	2.48	9.00	9.00
Caliper	2.85	0.26	0.07	2.90	2.90
Mullen (burst)	9.61	3.22	10.35	10.35	10.35
Tensile (md)	3.86	0.86	0.74	3.54	3.54
Tensile (cd)	1.38	0.45	0.20	1.53	1.53
Tear (md)	19.48	2.76	0.47	20.00	20.00
Tear (cd)	28.76	7.00	3.08	28.00	28.32
Bold (md)	6.07	5.53	30.57	5.71	5.71
Bold (cd)	43.67	26.68	711.73	58.62	58.62

Table #3: Paper Test Results For Litho

Paper Property	mean	std.dev.	variance	median	mode
Brightness	57.42	1.60	2.55	57.43	56.30
Opacity	91.38	1.42	2.02	91.38	90.38
Smoothness (10 kgf/cm ²)	4.83	0.06	0.00	4.84	4.79
Smoothness (20 kgf/cm ²)	3.72	0.36	0.13	3.72	3.72
Gloss	11.08	1.60	2.58	11.14	11.14
Wax Pick	8.49	0.71	0.50	8.50	8.00
Caliper	3.16	0.00	0.00	3.16	3.16
Mullen (burst)	7.77	2.38	5.68	7.96	6.27
Tensile (md)	2.94	0.88	0.78	2.94	2.06
Tensile (cd)	1.16	0.12	0.09	1.16	1.04
Tear (md)	17.36	0.88	0.05	4.34	4.19
Tear (cd)	23.00	2.96	0.55	5.78	5.25
Fold (md)	3.53	1.48	2.20	3.68	2.63
Fold (cd)	16.54	9.12	83.20	17.75	11.30

DISCUSSION OF RESULTS

DESIGNING OF SPECIFICATIONS

The paper specifications for flexography were designed based on the test results from the laboratory. These specifications are the average values (\pm the standard deviations) of the paper being used and, unfortunately, cannot represent all flexographic newsprint used in the industry. However, these numbers are the values which, based on this testing, are suggested as flexographic newsprint specifications. These specifications have been designed to lower the costs for the paper producer and for the printer. The bases for this are:

- *The paper producer can now base their paper properties on a set of specifications because they know what the printer needs for flexography.

- *Both the printer and the papermaker will have less complaint rolls of paper from the printer due to the problem that the paper will not print well on the flexographic printing presses.

- *The printer can now base their paper purchases on a set of specifications, helping to avoid the purchase of the wrong paper for their presses.

The following table, Table #4, is a list of the designed specifications for flexographic newsprint. Also, Table #5 is a list of designed paper specifications for lithographic newsprint.

Table #4: Designed Flexographic Newsprint Paper Specifications

Brightness	57.0 - 59.5%
Opacity	85.0 - 90.0%
Smoothness (10/20 kgf/cm ²)	5.0-5.5/4.0-4.5 microns
Gloss	9.5 - 11.5%
Wax Pick	7 - 9
Caliper	2.5 - 3.0 mils
Mullen (burst)	6.5 - 12.5 psi
Tensile (Instron) (md/cd)	3.0-4.5/1.0-2.0
Tear (md/cd)	17-22/23-33 gf

Table #5: Designed Lithographic Newsprint Paper Specifications

Brightness	55.8 - 59.0%
Opacity	90.0 - 93.0%
Smoothness (10/20 kgf/cm ²)	4.75-5.0/3.4-4.1 microns
Gloss	7.5 - 12.7%
Wax Pick	7 - 9
Caliper	3.0 - 3.25 mils
Mullen (burst)	5.4 - 10.2 psi
Tensile (Instron) (md/cd)	2.0-4.0/1.0-1.3
Tear (md/cd)	16.5-18.25/20-26 gf

These two specifications lists were both derived the same way (from the paper testing results), and are shown together for the purpose of comparing lithographic newsprint to flexographic newsprint to determine if there are any differences between the two papers.

COMPARISON OF SPECIFICATIONS

When comparing these two lists of specifications, a few differences can be seen. These differences include:

- *The brightness of the flexographic specs is a little higher than that needed for the lithographic paper.

- *The opacity of the lithographic is considerably higher than that needed for the flexographic newsprint. This due to the types of inks used in each process - the lithography process uses oil-based inks which tend to have a greater effect on the opaqueness a sheet of paper if the paper is not high in opacity. The flexography process uses water- and alcohol-based inks which dry more rapidly and do not need the higher opacity in the paper sheet.

- *The smoothness of the flexographic newsprint is also lower than that of the lithographic paper. This is contradictory to what was predicted in the theoretical discussion section. The flexography process needs a smooth sheet of paper because of the direct printing from the photopolymer plate, however the lithography process also needs a smooth sheet to transfer the ink

from a flat metal plate to the paper. The difference in these two values represents the difference between the rubber or photopolymer plate and the aluminum plate.

*The gloss of the two papers falls within the same ranges however with the paper tested here the litho has a much broader range to fall between.

*The wax pick of the two papers was about the same and the specifications for the two types of papers is the same. However, from the actual paper test results, the flexo paper had a slightly higher average than did the litho paper; and this would be expected since the flexo paper comes in direct contact with the printing plate and the plate cannot tolerate plate fill-in from the paper.

*The caliper of the flexographic newsprint is slightly lower than that of the lithographic newsprint; and this trend is probably because of the papers which were tested here. In the industry the caliper of newsprint for all processes is within the same range of 2.5 to 3.5 mils. Any difference seen here is only due to these different newsprints which were tested.

*The mullen (burst) test showed the flexographic newsprint as being higher in burst strength than the lithographic paper. This is not a highly reliable test, and this could be used as a secondary test after all the other tests have been run, just for comparison. But this test should not be used as the basis to

throw paper out.

*The flexographic newsprint showed slightly higher values for the tensile (Instron) and for the tear tests, than did the lithographic paper. This shows a slightly stronger sheet of paper is used for the flexo process than is used for the litho process.

*The fold test is not included in these specifications because it is a very unreliable test, and no set values can be placed on each set of newsprint. However, the results in Tables #2 and #3 show that the flexographic newsprint had higher average fold values than did the lithographic newsprint, which reinforces the statement that the flexographic paper is generally a stronger sheet of paper.

CONCLUSIONS/RECOMMENDATIONS

The average values from the testing, and the specifications which were derived from them, represent the best conclusions of this study. The paper properties which seemed to differ the most between the lithographic newsprint and the flexographic newsprint, and appeared to be the best judge of a good flexographic paper are: slightly lower smoothness, higher brightness, lower opacity, and higher strength.

My overall conclusions from this project include the specifications shown in Table #4, and the finding that there is not much published information available in this area.

Further work could be done in this area, and is being done, by a few of the flexographic printing companies and by others. The companies which I received samples from stated that this is an area which needs continued research. This project could be furthered with more time and more equipment.

LITERATURE CITED

- (1) Glassman, Alex, "Printing Fundamentals", Atlanta, GA, TAPPI Press, 1985, p.45-46.
- (2) Adams and Faux, "Printing Technology", 2nd ed., Belmont, CA, Delmar Publishers, 1982, p.589.
- (3) "Flexography", 2nd ed., New York, Flexographic Technical Association, 1970, p.11.
- (4) Bureau, William H., "What the Printer Should Know About Paper", U.S.A., Graphic Arts Technical Foundation, 1982.
- (5) Rendulic, Francis J., TAPPI Proceedings: 1988 International Printing and Graphic Arts Conference, (1988), p.37-39.

APPENDIX I: RAW TEST DATA

CHICAGO TRIBUNE

weight	bas. wt.	brightness	opacity	smooth(10)	smooth(20)	gloss	caliper	mullen
1.281	44.17	58.5	87.4	6.20	4.80	8.70	3.00	7.25
1.325	45.69	58.4	86.0	6.00	4.50	7.80	2.90	5.50
1.303	44.93	60.5	84.4	5.05	3.95	7.10	2.90	8.50
1.350	46.55	60.6	84.4	5.10	4.00	7.90	2.50	6.50
		61.0	86.2	5.40	4.20	6.80	2.90	7.50
	average =	60.9	86.2	6.40	4.85	9.00	3.00	8.25
	45.34 g/m ²	60.5	86.3	6.45	4.90	9.10	2.90	7.00
		59.0	86.4	5.10	3.95	9.10	3.00	6.75
		60.1		5.65	4.25	10.40	3.00	
		58.9	average =			8.90		average =
		60.8	85.91 %	average =	average =	7.30	average =	7.16 psi
				5.71	4.36		2.90 mils	
		average =				average =		
wax pick		59.93 %				8.37		
8								

tear(md)	tear(cd)	fold(cd)	fold(md)	tensile(md)	tensile(cd)
4.00	10.00	53	0	1.90	0.80
4.00	15.00	79	0	2.25	0.80
4.00	13.00	69	won't	3.85	0.80
4.50	12.00		hold	3.05	0.70
4.00	11.00	average =		3.20	0.75
3.50	12.00	67.0	average =	3.50	0.75
4.00	10.00		0.0	4.00	0.80
4.00	9.00			3.45	0.85
4.00	10.00			3.60	
4.00	9.00				average =
4.00				average =	0.78
	average =			3.20	
average =	11.10				
4.00	(14 plies)				
(14 plies)					

DIRECTORY from GREAT NORTHERN PAPER

bas.wt.	brightness	opacity	smooth(10)	smooth(20)	gloss	caliper	mullen
24.7#	60.0	82.3	5.45	4.20	9.20	2.50	7.50
(25X38/500)	59.6	86.4	5.50	4.25	7.90	2.40	8.50
as reported	59.4	84.3	5.45	4.30	10.80	2.40	7.00
by company	59.5	81.9	4.95	4.00	9.60	2.20	10.00
	59.0	83.2	5.45	4.30	9.80	2.30	7.00
	59.2	83.9	5.30	4.10	10.50	2.30	9.25
	60.2	83.2	5.40	4.25	8.50	2.30	8.50
	59.9	82.1	5.35	4.05	11.80	2.30	8.50
	59.4	83.9	5.10	4.00	10.20	2.30	5.50
	59.6	83.8			10.20	2.20	7.00
	59.9	83.3	average =	average =	9.40	2.30	6.00
wax pick	59.4	82.6	5.34	4.36		2.40	7.00
6	59.9	83.5			average =	2.20	7.00
	59.4	83.9			9.81	2.40	8.50
	59.9	83.4				2.30	7.75
	59.7	81.6				2.40	7.75
							7.50
	average =	average =				average =	
	59.62 %	83.33 %				2.32 mils	average =
							7.61 psi

tear(md)	tear(cd)	fold(md)	fold(cd)	tensile(md)	tensile(cd)
5.00	5.00	5	22	3.85	0.90
5.00	5.00	6	18	3.15	1.10
5.00	6.00	0	22	3.00	1.15
4.50	5.50	0	15	2.80	1.15
4.00	5.50	5	20	3.00	1.15
3.50	5.00	0	28	3.25	1.20
4.50	5.00	4	18	3.35	1.10
4.00	6.00	2	17	3.35	1.10
4.50	6.00	3	32	3.52	1.10
4.50	5.50		45	3.10	1.20
		average =		3.20	1.15
average =	average =	2.78	average =	3.15	0.95
4.45	5.45		21.33	3.30	0.95
(I4 plies)	(I4 plies)			3.35	
				3.75	average =
					1.09
				average =	
				3.27	

EVENING EXPRESS from Portland, Maine

weight	bas. wt.	brightness	opacity	smooth(10)	smooth(20)	gloss	caliper	mullen
1.334	46.00	55.7	85.2	5.30	4.00	12.40	3.00	4.00
1.326	45.72	55.7	86.9	5.35	4.05	13.30	3.00	4.50
1.305	45.00	56.3	85.0	5.35	3.90	10.40	2.80	4.50
1.293	44.59	56.9	84.9	5.85	4.50	10.20	2.80	6.00
1.310	45.17	57.5	85.1	5.70	4.40	10.20	3.00	6.25
1.327	45.76	58.7	85.0	5.70	4.30	12.90	2.80	7.50
1.334	46.00	58.9	84.8	5.30	4.10	10.90	2.90	5.00
1.317	45.41	58.1	85.2	5.40	4.20	9.60	2.80	8.00
		58.7		5.05	3.90	11.50	2.90	9.00
	average =		average =	5.30	3.95	12.10	3.00	7.00
	45.46 g/m2	average =	85.26 %			9.80	3.10	6.50
		57.32 %		average =	average =	10.20	3.00	7.25
				5.43	4.13			7.25
wax pick						average =	average =	5.00
9						11.12	2.92 mils	

average =
6.27 psi

tear(md)	tear(cd)	fold(cd)	fold(md)	tensile(md)	tensile(cd)
6.00	7.00	21	3	3.70	1.05
5.00	6.50	53	4	3.80	1.32
6.00	7.00	28	2	3.70	1.32
6.00	7.00	59	0	2.85	1.25
5.00	7.00	27	0	3.10	0.75
6.00	7.50	31	0	3.90	1.28
4.50	7.00	39	5	3.70	1.35
4.00	7.50	60		3.55	1.30
4.00	7.00		average =		1.10
4.50	6.50	average =	2.00	average =	
5.00	7.50	39.75		3.54	average =
4.00	6.50				1.91

average = average =
5.00 7.00
(14 plies) (14 plies)

GREATER BUFFALO PRESS

weight	bas. wt.	brightness	opacity	smooth(10)	smooth(20)	gloss	caliper	mullen
1.455	50.17	57.2	89.3	5.00	4.25	11.70	2.80	10.00
1.466	50.55	57.4	89.4	4.85	3.95	12.10	2.85	9.75
1.437	49.55	57.4	90.3	4.95	4.05	11.00	2.85	9.25
1.450	50.00	57.3	89.4	5.25	4.35	11.90	2.85	9.50
1.464	50.48	58.6	90.5	4.95	4.15	12.30	2.90	11.25
1.467	50.59	58.2	91.1	5.45	4.45	10.30	2.90	10.25
1.453	50.10	59.1	89.0	5.45	4.50	11.70	2.85	10.00
1.476	50.90	59.2	89.5	5.40	4.45	11.70	2.80	11.25
		58.5	90.0	4.70	3.80	12.10	2.85	9.00
	average =	58.1	92.2	5.10	4.10	11.80	2.85	9.75
	50.29 g/m ²	57.8	91.2			10.20		10.25
		58.0	91.3	average =	average =	10.30	average =	10.25
				5.11	4.20		2.85 mils	12.00
wax pick		average =	average =			average =		11.00
11		58.07 %	90.27 %			11.42		11.50
								11.00
								9.75
								10.50

average =
10.35 psi

tear(md)	tear(cd)	fold(cd)	fold(md)	tensile(md)	tensile(cd)
7.00	7.00	13	8	3.20	1.65
5.50	7.00	13	12	3.10	1.80
6.00	8.00	15	4	3.30	1.80
6.00	7.00	14	8	3.35	1.80
5.50	7.00	22	9	3.20	1.85
7.00	6.00	18	8	3.20	1.75
7.00	7.00		10	3.25	1.70
5.50	5.00	average =		3.50	1.60
6.00	7.00	15.83	average =		
6.00	7.00		8.43	average =	average =
6.00	7.00			3.26	1.74
6.00	7.00				
average =	average =				
6.12	6.83				
(14 plies)	(14 plies)				

GREATER BUFFALO PRESS

weight	bas. wt.	brightness	opacity	smooth(10)	smooth(20)	gloss	caliper	mullen
1.455	50.17	57.2	89.3	5.00	4.25	11.70	2.80	10.00
1.466	50.55	57.4	89.4	4.85	3.95	12.10	2.85	9.75
1.437	49.55	57.4	90.3	4.95	4.05	11.00	2.85	9.25
1.450	50.00	57.3	89.4	5.25	4.35	11.90	2.85	9.50
1.464	50.48	58.6	90.5	4.95	4.15	12.30	2.90	11.25
1.467	50.59	58.2	91.1	5.45	4.45	10.30	2.90	10.25
1.453	50.10	59.1	89.0	5.45	4.50	11.70	2.85	10.00
1.476	50.90	59.2	89.5	5.40	4.45	11.70	2.80	11.25
		58.5	90.0	4.70	3.80	12.10	2.85	9.00
	average =	58.1	92.2	5.10	4.10	11.80	2.85	9.75
	50.29 g/m ²	57.8	91.2			10.20		10.25
		58.0	91.3	average =	average =	10.30	average =	10.25
				5.11	4.20		2.85 mils	12.00
wax pick		average =	average =			average =		11.00
11		58.07 %	90.27 %			11.42		11.50
								11.00
								9.75
								10.50

average =
10.35 psi

tear(md)	tear(cd)	fold(cd)	fold(md)	tensile(md)	tensile(cd)
7.00	7.00	13	8	3.20	1.65
5.50	7.00	13	12	3.10	1.80
6.00	8.00	15	4	3.30	1.80
6.00	7.00	14	8	3.35	1.80
5.50	7.00	22	9	3.20	1.85
7.00	6.00	18	8	3.20	1.75
7.00	7.00		10	3.25	1.70
5.50	5.00	average =		3.50	1.60
6.00	7.00	15.83	average =		
6.00	7.00		8.43	average =	average =
6.00	7.00			3.26	1.74
6.00	7.00				
average =	average =				
6.12	6.83				
(14 plies)	(14 plies)				

KALAMAZOO GAZETTE

weight	bas. wt.	brightness	opacity	smooth(10)	smooth(20)	gloss	caliper	mullen
1.398	48.21	56.5	90.2	4.85	4.00	13.30	3.20	7.00
1.391	47.97	56.4	91.2	4.85	4.10	10.20	3.15	5.50
1.399	48.24	58.0	89.9	4.90	3.95	14.00	3.05	6.50
1.401	48.31	55.4	90.3	4.65	3.75	11.50	3.15	5.75
1.395	48.10	55.2	90.2	4.95	4.10	12.60	3.20	6.60
1.402	48.34	56.3	90.7	4.80	3.95	13.00	3.25	6.75
1.360	46.90	56.3	90.4	4.85	3.95	15.40	3.20	6.75
1.407	48.52	56.4	90.7	4.75	3.90	12.20	3.05	6.00
		55.9	90.6	4.90	4.05	10.70	3.20	6.00
	average =	57.8	90.2	5.05	3.90	11.10	3.15	7.70
	48.01 g/m ²	55.2	89.4	5.10	4.15	12.00	3.20	6.50
		57.2	90.5			11.90	3.20	6.00
		54.9	90.5	average =	average =	13.40	3.10	5.75
wax pick		56.0	90.8	4.88	3.98	12.90	3.20	5.25
8		55.5	90.2			10.90		6.50
			90.3			11.20	average =	5.75
		average =					3.164 mils	
		56.30 %	average =			average =		average =
			90.38 %			12.27		6.27 psi

tear(md)	tear(cd)	fold(cd)	fold(md)	tensile(md)	tensile(cd)
4.00	5.00	9.00	5.00	2.00	1.10
4.00	6.00	12.00	4.00	1.90	0.85
3.50	5.50	18.00	2.00	1.90	1.25
4.00	5.00	6.00	3.00	2.40	1.10
5.00	5.50	16.00	4.00	2.10	1.10
4.50	6.00	9.00	6.00	1.75	0.95
4.50	4.00	9.00	3.00	2.20	1.00
4.00	5.00	10.00	4.00	2.25	1.05
		12.00	3.00	1.25	1.00
average =	average =	12.00	4.00	2.40	1.05
4.19	5.25		3.00	2.00	1.00
(14 plies)	(14 plies)	average =		2.05	1.00
		11.30	average =	2.40	
			3.73	2.20	average =
					1.04
				average =	
				2.06	

K-FLEX from KRUGER, INC.

weight	bas. wt.	brightness	opacity	smooth(10)	smooth(20)	gloss	caliper	mullen
1.399	48.24	57.2	89.5	5.25	4.15	11.10	3.20	12.50
1.385	47.90	57.6	89.6	6.00	4.75	11.20	3.20	12.00
1.409	48.59	58.8	90.1	4.95	3.70	12.00	3.25	14.25
1.402	48.34	58.1	90.3	5.25	4.00	12.10	2.90	14.00
1.409	48.59	57.3	90.3	5.50	4.25	12.20	3.00	13.25
1.425	49.14	58.1	90.0	5.60	4.45	11.50	3.05	11.00
1.390	47.93	58.0	90.0	5.40	4.25	10.80	3.10	12.75
1.399	48.24	57.5	91.1	5.75	4.40	11.40	3.05	11.00
		59.5	89.9	5.10	4.10	10.70	3.10	13.50
	average =	60.2	91.5	5.25	4.15	11.00	3.10	8.50
	48.37 g/m2	60.4	90.6	5.20	4.25	11.20		11.00
		60.1	90.3			10.80	average =	12.75
				average =	average =	9.10	3.10 mils	11.50
wax pick		average =	average =	5.39	4.22	12.40		12.00
10		58.57 %	90.27 %			12.80		
						11.10		average =
						11.10		12.14 psi
						11.70		
						average =		
						11.34		

mullen	tear(md)	tear(cd)	fold(cd)	fold(md)	tensile(md)	tensile(cd)
12.50	5.00	7.00	69	8	4.30	1.50
12.00	4.00	7.00	30	10	4.15	1.55
14.25	4.00	7.00	86	3	4.35	1.50
14.00	5.00	7.00	65	5	4.20	1.70
13.25	4.50	7.00	51	6	4.25	1.50
11.00	5.00	7.00	55	2	4.70	1.50
12.75	4.00	8.00	55	6	3.90	1.65
11.00	4.50	7.00	58		4.65	1.30
13.50		7.00		average =		
8.50	average =	8.00	average =	5.71	average =	average =
11.00	4.50	7.00	58.62		4.31	1.52
12.75	(X4 plies)	6.00				
11.50						
12.00		average =				
		7.08				
average =		(X4 plies)				
12.14 psi						

NEWS from GREAT NORTHERN PAPER

bas.wt.	brightness	opacity	smooth(10)	smooth(20)	gloss	caliper	mullen
33#	56.4	90.0	5.35	4.20	11.40	2.90	15.50
(25X38/500)	56.6	90.1	4.90	3.90	11.50	3.00	14.75
as reported	56.7	89.2	5.45	4.25	13.00	3.10	13.50
by company	56.8	89.1	6.05	4.70	10.60	3.10	14.25
	56.3	91.8	4.85	3.80	10.40	3.10	16.25
	56.3	87.2	5.15	4.10	11.50	3.10	13.00
	56.6	89.3	5.25	4.20	11.30	3.00	16.00
	56.7	89.3	5.35	4.20	11.30	3.10	15.00
	56.7	89.9	5.25	4.10	10.70	3.00	14.00
	56.5	88.9	4.85	3.80	9.30	3.00	16.00
	56.4	90.4			11.40	3.10	15.25
wax pick	56.5	89.8	average =	average =	11.60	3.10	16.75
9	56.6	89.9	5.24	4.12	11.10	3.10	15.50
	56.8	89.4			10.70	3.20	17.50
	56.8	90.2			10.90	3.10	15.50
	56.9	90.0				3.10	17.00
	56.6	89.4			average =		13.50
	56.6	89.2			11.11	average =	15.75
	56.5					3.07 mils	14.00
	average =	average =					average =
	56.59 %	89.62 %					15.21 psi

tear(md)	tear(cd)	fold(md)	fold(cd)	tensile(md)	tensile(cd)
4.50	7.00	10	47	5.85	2.10
5.50	7.00	23	75	6.10	2.10
5.00	8.00	14	97	5.20	2.10
5.50	6.50	11	127	4.80	2.10
5.00	7.00	17	86	5.30	2.00
5.00	7.50	14	98	5.60	2.05
5.00	6.50	28	81	5.85	2.00
5.50	7.00	14	99	5.70	2.15
5.00	6.50	10	114	6.10	2.10
4.50	7.00	26	108	5.40	2.05
4.50	7.50		63	6.05	2.15
5.00	7.50	average =		4.40	2.10
		16.70	average =	4.70	
average =	average =		90.45	5.80	average =
5.00	7.08				2.08
(14 plies)	(14 plies)			average =	
				5.49	

NORLITE from GREAT NORTHERN PAPER

bas.wt.	brightness	opacity	smooth(10)	smooth(20)	gloss	caliper	mullen
30.8#	59.0	87.9	5.20	4.25	9.90	2.90	13.00
(25X38/500)	58.2	89.2	5.25	4.25	9.60	2.90	10.50
as reported	59.1	88.7	5.20	4.25	11.10	2.80	13.00
by company	58.8	89.2	5.40	4.15	9.60	2.80	11.50
	59.2	88.6	5.70	4.45	11.10	3.00	12.00
	59.5	89.2	5.25	4.30	9.50	2.90	9.75
	58.8	88.4	5.10	4.15	11.00	2.80	10.75
	58.6	88.7	5.10	4.20	9.20	2.90	12.00
	59.2	87.4	5.20	4.25	9.90	2.90	13.00
	59.0	89.3	5.30	4.40	10.00	2.80	9.25
	58.6	89.5			9.60	2.90	11.50
wax pick	58.9	88.9	average =	average =	10.20	2.80	10.75
9	58.6	90.1	5.32	4.26	11.50	2.75	9.50
	59.0	89.5			8.40	2.90	12.25
	60.1	89.4				2.90	12.75
	59.7	90.4			average =	3.00	14.00
					9.44		
	average =	average =				average =	average =
	59.02 %	89.02 %				2.87 mils	11.59 psi

tear(md)	tear(cd)	fold(md)	fold(cd)	tensile(md)	tensile(cd)
5.00	7.00	4	53	4.85	1.80
5.00	6.50	3	51	4.20	1.60
5.00	6.50	11	75	4.40	1.68
6.00	6.00	10	100	4.40	1.85
5.00	7.00	6	47	4.55	1.75
5.50	7.00	9	82	4.45	1.83
5.00	7.00	6	91	4.65	1.75
5.00	6.50	3	36	3.05	1.70
6.00	7.00	5	33	4.50	1.60
5.00	8.00	4	67	4.40	1.70
5.50	7.00	7		5.05	1.72
			average =	4.75	1.70
average =	average =	average =	63.5	4.80	1.75
5.27	6.86	6.78		4.50	1.75
(14 plies)	(X4 plies)			average =	average =
				4.47	1.73

WESTERN HERALD

weight	bas. wt.	brightness	opacity	smooth(10)	smooth(20)	gloss	caliper	mullen
1.485	51.21	55.3	91.4	4.65	3.45	10.20	3.00	9.00
1.495	51.55	59.0	91.5	4.55	3.50	12.50	2.90	10.50
1.440	49.66	59.4	92.6	5.00	3.75	9.40	3.00	11.00
1.396	48.14	57.7	94.0	5.20	3.85	10.40	3.00	9.00
1.382	47.66	56.8	93.2	4.50	3.40	12.00	3.00	10.00
1.384	47.72	58.0	93.5	5.00	3.85	8.20	3.40	10.75
1.420	48.97	59.9	93.0	4.75	3.50	8.40	3.30	8.75
1.428	49.24	59.7	92.5	4.85	3.55	8.90	3.20	8.75
		57.7	91.8	4.60	3.40		3.20	10.50
	average =	58.4	91.4			average =	3.25	10.00
	49.27 g/m ²	59.2	92.3	average =	average =	10.00	3.30	9.50
		59.0	92.1	4.79	3.47		3.30	11.00
		59.5	91.4				3.20	9.50
wax pick		59.6	91.7				3.20	9.50
9		60.0	93.2				3.10	9.00
		57.8	92.7				3.20	7.50
		average =	average =				average =	average =
		58.56 %	92.39 %				3.16 mils	9.64 psi

tear(md)	tear(cd)	fold(md)	fold(cd)	tensile(md)	tensile(cd)
4.50	6.00	3	37	3.20	1.10
4.50	7.00	0	33	3.95	1.30
4.50	6.50	3	24	4.05	1.15
4.50	4.50	0	26	3.80	1.45
5.00	6.50	3	16	4.20	1.20
4.00	5.00	4	30	3.45	1.45
4.50	7.00	5	17	4.20	1.20
	6.50	3	10	3.75	1.27
	6.50				
average =	7.50	average =	average =	average =	average =
4.50		2.63	24.20	3.825	1.27
(14 plies)					
	average =				
	6.30				
	(14 plies)				

Appendix II: TAPPI Standards Used for Testing

T-402	Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets and Related Products
T-403	Bursting Strength of Paper
T-410	Grammage of Paper and Paperboard (Weight Per Unit Area)
T-411	Thickness (Caliper) of Paper and Paperboard
T-414	Internal Tearing Resistance of Paper
T-425	Opacity of Paper
T-452	Brightness of Pulp, Paper, and Paperboard
T-459	Surface Strength of Paper (Wax Pick Test)
T-494	Tensile Breaking Properties of Paper and Paperboard (Using Constant Rate of Elongation Apparatus)
T-511	Folding Endurance of Paper (MIT Tester)