Relation between the K&N test and printability tests for newsprint

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ABSTRACT: The K&N ink stain test is commonly used in North America to predict the ink absorptivity of coated papers. Some publishers have shown interest in adapting the test for newsprint. However, many factors influence the results of the test performed on coated paper or on newsprint. We therefore have investigated the potential of the K&N test to predict the print properties. The study showed that the K&N test value is not strongly correlated with other printability tests where actual printing is performed. Only trends can be identified between the K&N value and the ink requirement, the ruboff, and the print-through at a print density of 0.85: the higher the K&N value, the higher are the ink requirements, the ruboff, and the print-through.

KEYWORDS: Ink rub resistance, newsprint, printability, print density, print quality, show, through, smearing, test methods.

The printablility of paper may be defined as its ability to receive ink in the printing operation to produce an image of good quality. This characteristic depends upon the interaction of many paper attributes: formation, roughness, compressibility, surface strength, opacity, porosity, etc. The most reliable, yet time consuming, printability analysis is performed in the laboratory through actual printing tests. Printing conditions such as speed, pressure, and ink properties are very well controlled in order to simulate commercial printing. Printability is evaluated through the analysis of the ink transfer and of the prints themselves. The prints are analyzed for print density, print-through, mottle (non-uniformity of the density) and contrast. All of these properties are very much influenced by the ink absorptivity of the paper.

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To save time, papermakers and printers have searched for a fast, simple, and effective test to predict how well the paper will print on a commercial press, without actually printing the paper. Ink stain tests—in which the paper is hand-smeared with ink—were designed to measure the ink absorptivity of coated papers. The most common of these tests in North America is the K&N test *(1)*. Contradictory results can be found in the literature concerning the usefulness of the K&N test in predicting the absorptivity of coated papers *(2–4)*. The K&N test is known to be influenced by surface roughness when performed on coated papers *(5–7)*.

Despite problems with the K&N test, some publishers have suggested the use of the K&N test for newsprint printability evaluation *(8)* and one has set a "recommended value" for its newsprint suppliers. Since no study establishes the usefulness of the K&N test on newsprint, we therefore investigated the capability of the K&N test to predict printing behavior of newsprint, by predicting ink absorptivity.

Experimental

Paper

Thirty-two newsprints from across Canada and the United States were tested on the top side. Physical properties of the samples are listed in the Appendix.

K & N Ink Test

Conditioning

All samples were conditioned at 50% RH and 23°C before testing, according to CPPA standard A.4.

K&N Testing

The procedure used is very similar to British Standard BS 4574:1970 *(1)*. Five stain tests on two randomly selected sheets were performed on each sample. The K&N ink was left in contact with the paper for 2 min. After the excess ink was wiped, the density of the stains were measured with a MacBeth densitometer. The density readings were converted to reflectance values and the K&N value (% drop in reflectance) was calculated according to

$$K\&N = 100(R - R_{stain})/R \qquad (1)$$

where

R = reflectance of the paper

R_{stain} = reflectance of the stain.

An increase in the K&N value corresponds to a greater amount of ink retained by the paper, and so to an increase in ink absorption. The reflectance of the reverse side of the stain was also measured as an indication of print-through, as described in the Gannett specifications *(8)*. The results of the K&N test can be found in **Table I.**

Appendix

Sample	Basis weight,* g/m²	Bulk, cm³/g	Caliper, µm	Parker Print-Surf Roughness, µm	Parker Print-Surf Air permeability, mL/min	Opacity, %
1	45.9	1.83	84.0	4.37	146.9	90.8
2	42.3	1.79	75.6	3.78	402.0	94.0
3	45.5	1.84	83.7	3.88	346.5	93.7
4	44.5	2.03	90.3	4.05	394.1	94.2
5	45.0	1.87	83.9	3.51	388.1	94.6
6	45.4	1.89	85.7	2.97	614.5	95.6
7	45.8	1.74	79.7	2.79	203.9	94.6
8	46.1	1.69	78.1	3.35	204.4	94.6
9	45.6	1.72	78.7	3.52	344.2	94.1
10	44.0	1.85	81.6	3.34	303.2	94.4
11	44.0	1.88	82.4	3.41	336.2	93.9
12	44.3	1.94	85.8	3.76	469.1	95.2
13	45.1	1.82	82.2	3.09	357.8	96.0
14	47.1	1.69	79.3	4.20	457.9	95.3
15	46.0	1.77	81.4	3.54	319.6	95.0
16	44.5	1.64	73.1	3.47	331.7	92.4
17	46.5	1.79	83.0	3.84	621.3	93.5
18	44.9	1.98	88.8	4.03	513.7	95.3
19	45.9	1.62	74.5	3.74	247.5	93.8
20	45.7	1.88	85.6	4.09	124.7	93.8
21	46.4	1.64	76.3	3.59	254.3	95.7
22	44.6	1.79	79.7	3.59	296.2	94.6
23	43.9	1.87	81.8	3.80	406.5	93.0
24	46.3	1.84	85.1	4.26	392.6	95.2
25	45.7	1.95	89.1	4.14	200.0	94.1
26	44.6	2.00	89.0	3.70	1137.7	95.1
27	41.4	1.71	70.7	3.76	348.1	93.0
28	45.6	1.86	84.8	4.61	379.8	94.9
29	44.3	1.83	80.9	3.55	410.0	95.5
30	44.2	1.91	84.5	3.84	279.3	94.8
31	42.6	1.83	78.0	4.21	879.6	93.3
32	44.7	1.59	71.1	3.72	290.8	84.4

*Oven-dried samples

Printability testing

The roughness and the air permeability of the samples were measured using the Parker Print-Surf Roughness Tester, digital model. The results can be found in the Appendix.

Samples were printed on the GFL laboratory rotary press according to the SCAN standard P35:72. The resulting prints were analyzed according to the SCAN standard P36:77. Ink requirement, print-through, set-off and ruboff *(9)* were measured at a print density of 0.85 and 1.00. The ruboff values are calculated according to an equation similar to the one used for print density, print-through and set-off:

$$RO = \log (R / R_p) \qquad (2)$$

where

R = reflectance of the unprinted paper

R_p = reflectance of the rubbed stain on the reference paper.

The print properties as measured by the SCAN test can be found in **Table II.**

Subjective evaluation

The K&N stains are sometimes used in the newsprint industry to assist in the subjective evaluation of the uniformity of ink sorption (mottle) and sheet formation. To test the relevance of this evaluation, we prepared 32 stains on each side of four newsprints whose K&N value spanned the range of the original 32 newsprints. The 256 resulting stains were randomly sorted and divided into 128 pairs. We asked 10 papermakers to separately judge the stains: once for darkness, and once for uniformity. The judges received the same pairs to compare. Quantitative measurements of the uniformity of the stains and of the paper formation were obtained by image analysis using the Paprican Microscanner. The RMS (root mean square), the specific perimeter and the average cluster area [which have been suggested for quantifying for-

I. K&N test results

Sample	% Drop of reflectance	% Drop in reflectance reverse side stain
1	49.9	15.7
2	56.5	6.2
3	50.8	10.0
4	52.1	14.0
5	53.2	10.0
6	41.0	4.9
7	47.3	10.0
8	43.2	10.8
9	53.4	14.1
10	52.8	12.9
11	53.2	13.7
12	51.0	10.0
13	47.8	10.8
14	50.6	14.5
15	49.9	15.3
16	50.8	18.3
17	49.4	14.9
18	50.6	13.7
19	50.3	18.0
20	45.0	10.0
21	51.9	15.3
22	41.9	8.4
23	43.7	11.7
24	47.5	10.5
25	48.7	12.5
26	49.2	10.9
27	49.6	15.7
28	49.4	11.3
29	51.2	11.7
30	43.5	10.0
31	54.3	20.6
32	52.6	15.3

mation and mottle *(10)*] of the unprinted papers and of the stains are given in **Table III**.

Results and discussion

Variation of the K&N test

The variation of the test within a sample and the week-to-week variation were calculated from measurements done on a set of 32 different newsprint samples. Each test result represents the mean of five determinations made on two randomly selected sheets for each sample. **Table IV** presents the average variation of the test result expressed as 95% confidence limits, expected at any given time or with any single set of tests. For the same samples, the table also shows the variation expressed as 95% confidence limits computed from tests carried out over an interval of two weeks. The higher value of the week-to-week variation indicates some additional variability in the test method with time. Statistically, in almost all cases, the lab-to-lab variation would be greater than the week-to-week variation computed in one specific laboratory.

We should note that the precision specified by Gannett (±3) is matched by the week-to-week variation of a single laboratory. Since the lab-to-lab variation would almost surely be greater, the acceptable variance specified by Gannett is unrealistic.

Correlation between the K&N test and printability tests

Table V presents the correlation coefficients calculated between the K&N test and various printability tests.

In order to establish with 99% confidence that apparent correlations are not just random fluctuations, the correlation coefficient must exceed 0.45 between the two properties. We cannot assert at that level of confidence that the K&N test is correlated with any of the other printability tests.

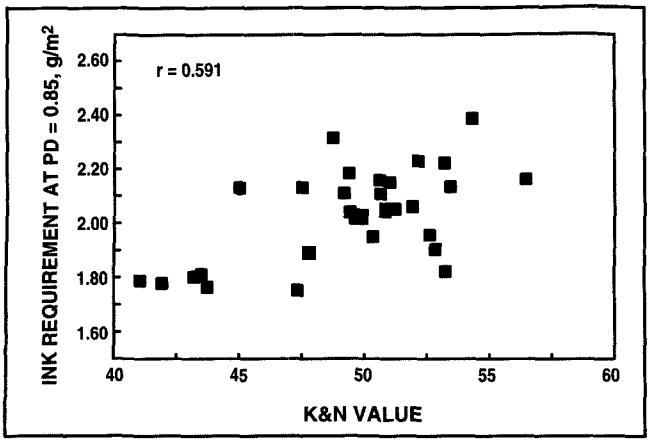
No correlations were found between the K&N value and either the roughness or the air permeability measured by the Parker Print-Surf. However, as stated by Chatwin *(7)* and Bristow *(5)*, roughness influences the K&N value. Bristow *(5)* found a reasonable correlation between the Parker Print-Surf roughness value and the K&N value extrapolated to zero contact time, defined as the roughness component of the K&N value.

However, ink requirement, print-through and ruboff at a print density of 0.85 show a trend with the K&N value. The set-off at the same density does not demonstrate any relation with the K&N value.

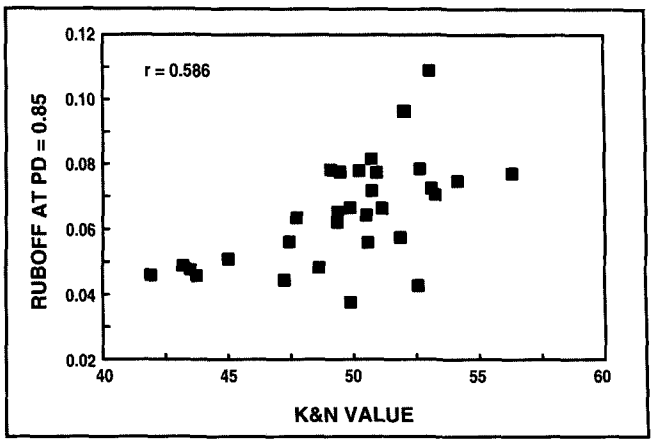
Figures 1, 2, and 3, respectively, show the relation between the K&N value and the ink requirement, the ruboff, and the print-through. Ink requirement and ruboff (Figs. 1 and 2) increase with the K&N value while print-through increases with the K&N value measured on the reverse side of the stain (Fig. 3).

The relations between the K&N value and the ink requirement, ruboff and print-through can be explained as follows. The higher the K&N value, the greater will be the amount of ink absorbed into the sheet and/or trapped in the valleys of the surface. This implies that more ink is needed

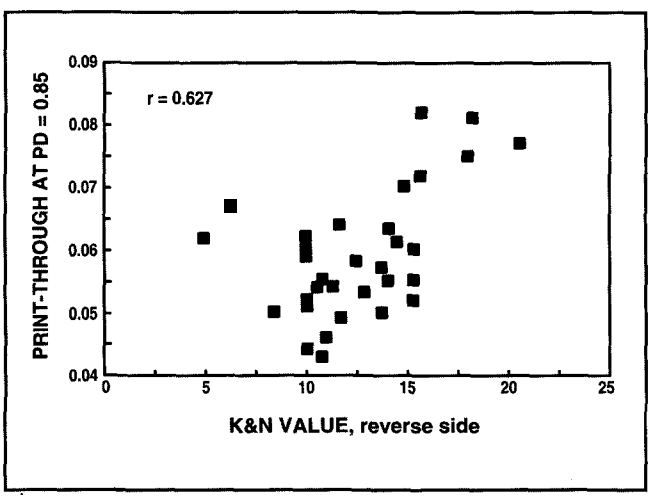
1. The ink requirement at a print density of 0.85 as a function of the K&N value



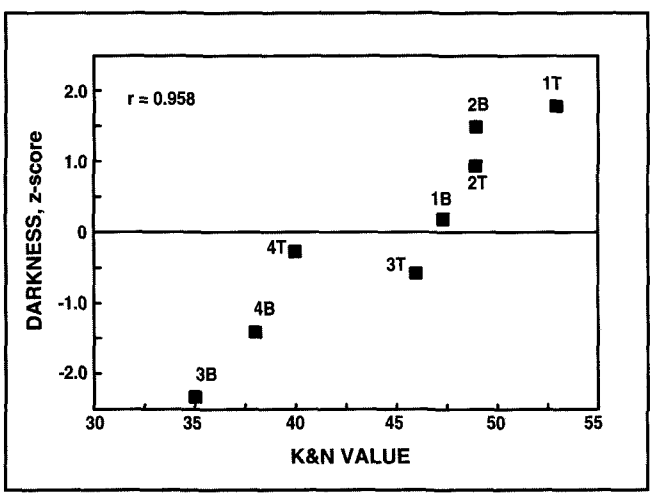
2. The ruboff at a print density of 0.85 as a function of the K&N value



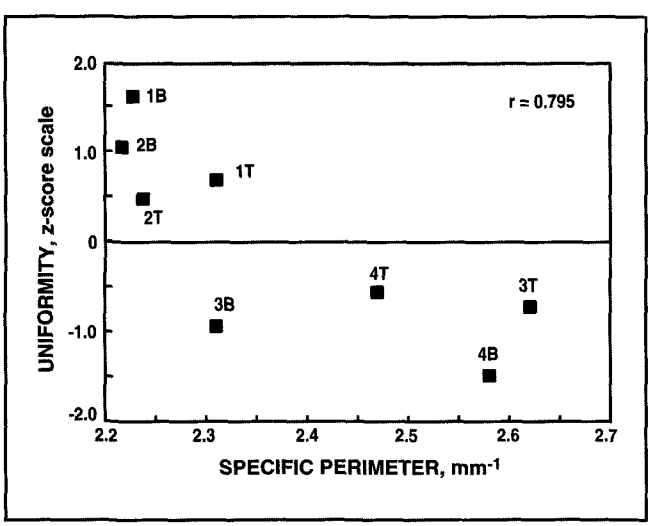
3. The print-through at a print density of 0.85 as a function of the K&N value, measured on the reverse side of the stain



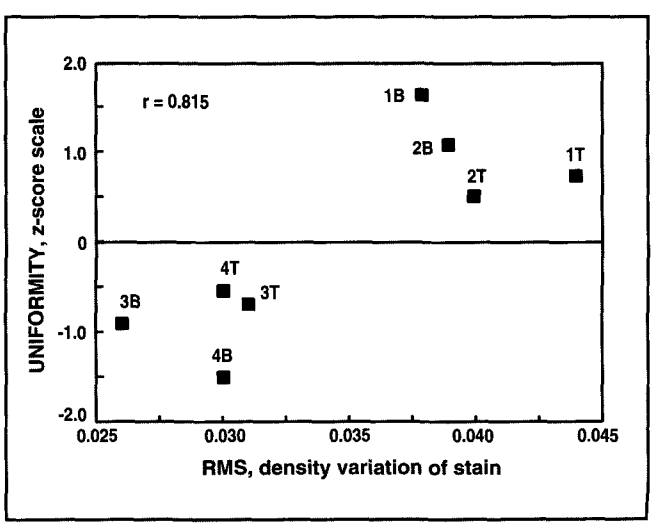
4. The subjective evaluation of the darkness of the stain as a function of the K&N value (measured with the Macbeth densitometer).



5. The subjective evaluation of the uniformity of the stain as a function of the specific perimeter



6. The subjective evaluation of the uniformity of the stain as a function of the RMS of the density variation of the stain



II. Print properties according to SCAN

Sample	IR 0.85, g/m²	IR 1.00, g/m²	PT 0.85	PT 1.00	SO 0.85	SO 1.00	RO 0.85	RO 1.00
1	2.02	3.18	0.082	0.105	0.167	0.386	0.038	0.055
2	2.16	3.64	0.067	0.095	0.216	0.459	0.076	0.098
3	2.04	3.44	0.059	0.080	0.187	0.411	0.071	0.091
4	2.23	3.69	0.055	0.074	0.218	0.428	0.096	0.117
5	2.22	3.70	0.062	0.076	0.228	0.423	0.108	0.136
6	1.79	3.10	0.062	0.076	0.228	0.423	0.108	0.136
7	1.75	3.24	0.051	0.072	0.234	0.719	0.044	0.077
8	1.80	3.06	0.055	0.075	0.247	0.607	0.049	0.071
9	2.13	3.52	0.063	0.089	0.196	0.411	0.070	0.089
10	1.90	3.16	0.053	0.073	0.251	0.475	0.078	0.101
11	1.82	3.08	0.050	0.068	0.184	0.526	0.072	0.095
12	2.15	3.69	0.052	0.075	0.253	0.478	0.077	0.103
13	1.89	3.62	0.043	0.064	0.229	0.673	0.063	0.089
14	2.16	3.80	0.061	0.089	0.211	0.548	0.056	0.076
15	2.03	3.37	0.055	0.075	0.241	0.575	0.066	0.089
16	2.05	3.48	0.081	0.114	0.213	0.526	0.081	0.105
17	2.04	3.47	0.070	0.094	0.234	0.561	0.065	0.089
18	2.11	3.75	0.057	0.081	0.201	0.553	0.064	0.090
19	1.95	3.34	0.075	0.105	0.185	0.497	0.078	0.100
20	2.13	3.75	0.060	0.087	0.218	0.500	0.051	0.070
21	2.06	4.41	0.052	0.090	0.237	0.693	0.057	0.092
22	1.78	3.70	0.050	0.082	0.216	0.621	0.046	0.076
23	1.77	3.20	0.064	0.087	0.185	0.512	0.046	0.076
24	2.13	3.91	0.054	0.083	0.275	0.684	0.056	0.089
25	2.32	4.19	0.058	0.091	0.216	0.465	0.048	0.073
26	2.11	3.72	0.046	0.067	0.288	0.646	0.078	0.102
27	2.02	3.61	0.072	0.101	0.223	0.469	0.077	0.098
28	2.18	3.86	0.054	0.076	0.199	0.475	0.062	0.084
29	2.05	4.12	0.049	0.076	0.252	0.659	0.066	0.085
30	1.81	3.26	0.044	0.063	0.199	0.590	0.048	0.077
31	2.39	4.16	0.077	0.114	0.252	0.480	0.074	0.103
32	1.95	3.77	0.060	0.091	0.203	0.634	0.042	0.081

IR 0.85 - IR 1.00: Ink requirement to obtain a print density of 0.85 or 1.00
PT 0.85 - PT 1.00: Print-through at a print density of 0.85 or 1.00
SO 0.85 - SO 1.00: Set-off at a print density of 0.85 or 1.00
RO 0.85 - RO 1.00: Ruboff at a print density of 0.85 or 1.00

to achieve a target print density. More ink on the surface would lead to ruboff *(9)*. A high reverse-side K&N value would correspond to a higher print through. This is due to an increase in the ink demand and an increase in penetration of vehicle and/or of the ink pigment into the sheet.

Principal component and classical factor analysis were performed on the data. However, due to the small number of observations, the number of variables was reduced to 11. The three major factors identified through the statistical analysis were the same as the ones shown by linear regression: ink requirement, ruboff, and print-through. However, two more factors representing set-off at a print density of 0.85 and the specific perimeter of the stains were identified. These two new factors accounted for only 1.5% of the total variance.

Subjective evaluation of the stains

The data obtained from the pair comparison of the 256 stains were analyzed on the assumption that judgments of darkness or uniformity are based on a normal preference distribution with mean zero and standard deviation 1. The proportion of times, P, that each sample was judged darker or more uniform than all of the others with which it was compared determines the position of the sample in the preference distribution. This proportion can be transformed to a z-score (standard normal deviate), which locates the sample on the judgment scale of mean zero and of standard deviation of 1. This is an arbitrary linear scale which can then be correlated with the physical properties of the paper believed to be responsible for the

III. Formation of the paper and uniformity of the stains measured by image analysis

Sample	Unprinted paper			Stains		
	Specific perimeter, mm^{-1}	Average cluster area, mm^2	RMS	Specific perimeter, mm^2	Average cluster area, mm^2	RMS
1	2.75	1.54	0.092	2.20	2.00	0.031
2	2.85	1.49	0.100	2.39	1.61	0.028
3	2.72	1.56	0.097	2.12	2.07	0.031
4	2.85	1.71	0.115	2.12	2.26	0.034
5	2.83	1.47	0.102	2.01	2.05	0.035
6	2.65	1.57	0.080	2.13	1.67	0.028
7	3.02	1.44	0.081	2.39	1.68	0.028
8	2.72	1.73	0.094	2.12	2.17	0.027
9	2.55	1.82	0.121	2.22	2.09	0.034
10	2.64	1.77	0.100	2.20	1.87	0.030
11	2.61	1.90	0.116	2.30	2.04	0.031
12	3.00	1.61	0.110	2.24	1.90	0.030
13	2.85	1.63	0.104	2.08	2.07	0.029
14	2.96	1.53	0.127	2.19	1.91	0.028
15	2.96	1.64	0.096	1.88	2.47	0.027
16	2.82	1.58	0.102	1.82	2.00	0.029
17	2.98	1.76	0.107	1.85	2.33	0.029
18	3.07	1.38	0.104	2.08	2.14	0.027
19	3.00	1.69	0.088	2.09	2.18	0.026
20	3.01	1.54	0.088	2.31	2.13	0.027
21	3.10	1.43	0.092	2.51	1.91	0.025
22	3.35	1.18	0.086	2.32	1.97	0.021
23	3.15	1.31	0.079	2.11	1.91	0.026
24	2.96	1.47	0.100	2.23	1.85	0.029
25	2.82	1.56	0.108	2.35	2.04	0.031
26	3.23	1.34	0.109	2.42	1.81	0.027
27	2.93	1.46	0.086	2.18	2.10	0.028
28	2.97	1.59	0.110	2.43	2.07	0.027
29	3.24	1.54	0.118	2.47	1.90	0.027
30	2.81	1.52	0.081	2.32	1.77	0.022
31	2.95	1.52	0.097	2.28	1.77	0.035
32	3.21	1.40	0.092	2.32	1.91	0.030

perceptual judgments of darkness and uniformity. The r values must be greater than 0.798 to be significant within the 99% confidence limit. The proportions and the z-scores are presented in **Table VI.**

The judges first ranked the stains according to their darkness. The reflectances of the stains were measured with an Elrepho 2000 photometer. The tristimulus *Y* reflectance ("Luminous Reflectance") was used because this spectral range is known to dominate the perception of lightness and darkness *(11)*. The subjective ranking correlates well with the K&N value calculated from Elrepho measurements (r = 0.918). Because a densitometer is normally used to measure the darkness of the stain, the stains were also measured on a Macbeth densitometer. The subjective evaluation of darkness correlates equally well with the K&N value calculated from Macbeth densitometer readings (r = 0.958). The relation is shown in **Fig. 4.** The Elrepho reflectances were converted into optical density values and correlated with the Macbeth density values. The r value was 0.943. We conclude that the subjective evaluation method is valid for the simple estimate of achromatic shade, that the results obtained from the

IV. Variations of the K&N test on newsprint

	95% Confidence limits of test result	Week-to-week variation at 95% confidence limit
% drop in reflectance	1.98	3.01
% drop in reflectance of the reverse side of stain	2.75	3.08

V. Correlations between the K&N test and other printability tests

Test	*r*
IR 0.85	0.591
IR 1.00	0.329
PT 0.85[a]	0.627
PT 1.00[a]	0.671
SO 0.85	-0.109
SO 1.00	-0.403
RO 0.85	0.586
RO 1.00	0.557
S10	0.184
P20	0.066
Printing opacity[a]	-0.175
Specific perimeter[b]	0.291
Average cluster area[b]	0.399
RMS[b]	0.449

[a]Correlations calculated with the K&N value measured on the reverse side of the stain.
[b]Correlations calculated between the unprinted paper and the stain.

NOTE: r value > 0.449 is significant at 1% probability level.

IR 0.85 - IR 1.00: Ink requirement to obtain a print density of 0.85 or 1.00
PT 0.85 - PT 1.00: Print-through at a print density of 0.85 or 1.00
SO 0.85 - SO 1.00: Set-off at a print density of 0.85 or 1.00
RO 0.85 - RO 1.00: Ruboff at a print density of 0.85 or 1.00
S10: Parker Print-Surf roughness, 1.0 MPa clamping pressure, soft backing
P20: Parker Print-Surf air permeability, 2.0 MPa clamping pressure

VI. Subjective evaluation: proportions and z-score

Sample	*Darkness*		*Uniformity*	
	P	*z-score*	*P*	*z-score*
1-T[a]	0.96	1.75	0.76	0.71
1-B[b]	0.53	0.08	0.95	1.64
2-T	0.82	0.92	0.69	0.50
2-B	0.93	1.48	0.86	1.08
3-T	0.28	-0.58	0.24	-0.71
3-B	0.01	-2.33	0.18	-0.92
4-T	0.39	-0.28	0.45	-0.55
4-B	0.08	-1.41	0.07	-1.48

[a]T = top side
[b]B = bottom side

Macbeth densitometer and the Elrepho are equally valid in this case, and that the judges themselves are capable of making useful distinctions.

Figures 5 and 6 show the relation between the subjectively judged uniformity of the stain and respectively the specific perimeter and the RMS of the stain density variation. Past observations of commercial prints have shown that the higher the specific perimeter and the lower the RMS, the better the uniformity of the print. That is, a print with a large number of small features and a small variation in density should be preferred. However, the results shown here regarding stains are contrary to this expectation. People apparently judged spotted stains as more uniform than the ones presenting a "salt and pepper" appearance.

This difference in uniformity perception may come from the difference in physical distribution of the ink between a commercial print and a K&N stain, and from the difference in color between commercial and K&N inks.

Ink distribution depends on how ink is transferred to the paper. In commercial printing, the ink comes in contact with the paper for a few milliseconds, under pressure. In the K&N test, the ink sits on the paper surface, with no applied external pressure. Ink penetration is due mostly to capillary action. These differences in ink transfer affect the pigment and vehicle distribution in the paper. In the K&N test, ink has time to fill the surface valleys and create larger spots than in commercial printing. Also, the contrast among different spots within a stain produced with a blue-gray ink is lower than between the inked and uninked portions of a print made with a black ink.

The two sides of the samples were tested to evaluate the perceived two-sidedness in ink absorption compared to the measured two-sidedness. From Fig. 4, we can

see that the subjective estimate of the darkness of a smear agrees well with K&N values. However, perceived nonuniformity in the smears correlates less well with the instrumental measurements of intensity nonuniformity (Fig. 5) and the scale of the nonuniformity (Fig. 6).

Conclusion

The K&N test is of limited use in predicting the print properties of newsprint testing. While trends have been identified between the K&N value and ink requirement, print-through and ruboff at a print density of 0.85, the correlations are weak. An excellent correlation was observed between the K&N value and the subjective evaluation of the stain darkness. However, the specific perimeter and the RMS of the stain do not correlate as well with the subjective evaluation of the stain uniformity (mottle).

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