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EVALUATING THE QUALITY OF PRESSURE SENSITIVE COPY PAPERS

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ABSTRACT

A reliable and reproducible testing procedure for the development, product improvement and production control of pressure sensitive copy papers (PSP) is described.

The crucial aspect of the testing procedure (FM-test) is the alignment of many small individual areas so close to each other that a full tone area results from the contact between and partial overlapping of the individual areas. The full tone area surface copies of practically any size, characterized by a very uniform appearance of intensity, can be measured very simply by means of commercially available remission photometers or densitometers. Another important aspect of the FM-test is very good reproducibility and adjustment of the writing force, which is the key to reliable conclusions concerning changes of quality and their causes.

Mathematical and statistical evaluations point out that the quality of PSP can be described by a "characteristic curve" (CC), showing the change of image intensity as a function of writing force. A three-parameter equation for the CC allows an easy calculation of several quality criteria characterising the PSP, without the need of performing a multitude of different tests. In an example, discussed in more detail, it is shown, which paper qualities affect the performance of a PSP and how quickly and reliably the correlations can be evaluated by the FM-test.

INTRODUCTION

A PSP has to meet many quality aspects, i.e. image intensity, print clarity, legibility, tendency towards smudging and copying behaviour in the set. These quality criteria are summarized in a market study of the GFM-CHEMIE (1).

Testing and evaluating all these quality criteria normally asks for several different test-procedures, most of which show the disadvantages of requiring a considerable expenditure on equipment and/or time (2, 3, 4, 5).

We have looked for an easy and quick method both in performing and evaluating the test. Furthermore it should result in reliable conclusions on several different quality criteria. In an earlier publication (6) we have reported the chronological development of the test in more detail - the FM-test.

Here we would like to concentrate on the mathematical and physical background of the test evaluation.

THE FM-TEST

Test procedure

One of the important quality criteria of a PSP is the maximun attainable image intensity, or contrast Km. For the determination of Km full tone area copies could be produced in the form of calender prints. Fig. 1 shows the misleading results achieved by doing this.

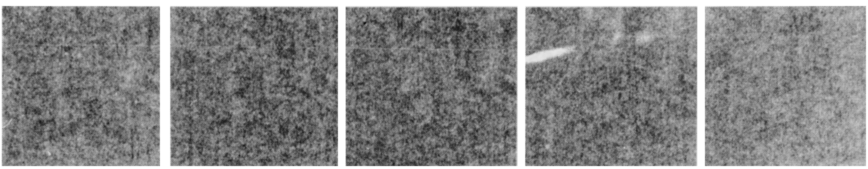


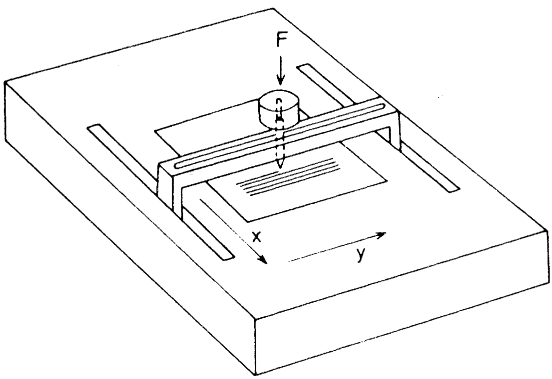
Fig 1—Copies 1 to 5 produced by the calender printing process with appropriate contrast values K.

In the calender prints no loss in intensity is obtained with an increasing number of copies which contradicts experience gained with typewriter and, in particular, high-speed printer copies.

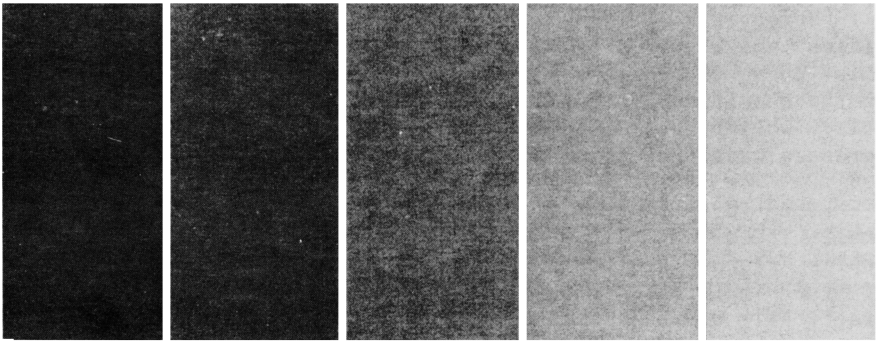
Moreover calender printing results in irregular image densities which is mainly due to paper formation influences. But this in no way corresponds to the actual conditions prevailing in the copying of individual characters (letters, figures, symbols) which react much less strongly to thickness/density differences caused by formation.

The FM-test avoids these disadvantages by aligning many small individual areas so close together that full tone area copies result from the contact between and partial overlapping of the individual areas, thereby producing full tone areas of practically any size desired.

The principle is shown in Fig. 2 diagrammatically: a stylus which can be loaded with various weights oscillates in y-direction and, at the same time, moves slowly with a constant velocity in x-direction. If both movements are matched properly, the result is full tone area copies of the desired length which are characterised by extraordinary uniformity of the image intensity, as shown in Fig. 3. As a result of the almost friction-free bearing of the stylus very good reproducibility and adjustment of the writing force is guaranteed.



The large full area copies can be measured very simply by means of commercially available remission photometers and/or densitometers.



K=71,3 K=64,8 K=51,2 K=35,3 K=24,2

Fig 3—Copies 1 to 5 produced with the FM-test procedure with appropriate contract values K.

Evaluating the FM-test

Testing a multiple set with stepwise varying writing forces and plotting image density versus writing force results in a diagram shown in Fig. 4.

Our measure for image density is contrast K, as defined by equation (1).

$$K = \frac{R\emptyset - R}{R\emptyset} \cdot 100 \qquad (1)$$

where K = contrast (%)
RØ = reflectance factor, nonimaged area (%)
R = reflectance factor, imaged area (%)

A similar form of display has already been chosen by Graham et. al. (3) and Grosse (5).

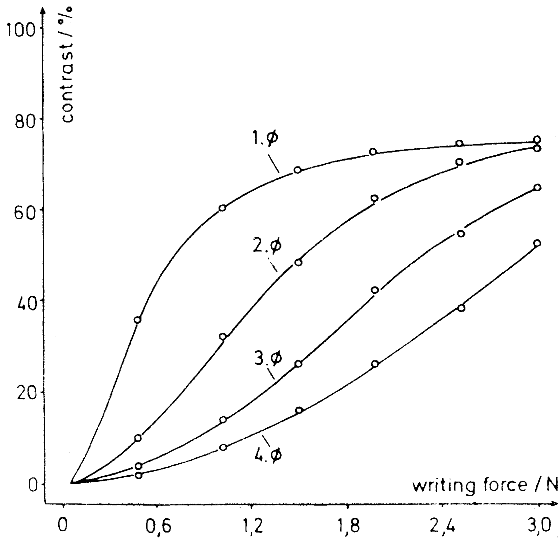


Fig 4—Characteristic curve display of the FM-test: contrast as a function of writing force.

The progression of the curves and their relative positions characterise very accurately a given PSP.

As seen from Fig. 4 the curves result from measuring a PSP set at six different writing forces. Following the testing conditions defined by us it takes about three minutes to produce a full tone area copy at a given writing force, so that a total of approximately twenty minutes is needed. Moreover, the reflectance of the individual copies has to be measured which comes up to 30 measurements when testing a set consisting of six single sheets. After that the 30 measured points have to be plotted into the contrast-writing-force-diagram. Therefore the expenditure on testing, measuring and evaluating is remarkable.

Moreover the question arises: which conclusions can be drawn from that relative complicated display?

All this led to the usage of a computer, producing the diagram by plotting the measuring points and, most important, calculating and drawing regression-curves free from subjective interpolation. The regression-curves are called "characteristic curves".

Mathematics of the characteristic curve (CC)

There is no mistake in the title of this chapter as one could probably suppose looking for the missing "s" in the word "curve". On the contrary, we will prove that all curves can be superimposed resulting in one single "characteristic curve". How is this possible and what is the meaning of this finding?

For all regression calculations the computer has to be told the mathematical equation the coefficients of which have to be determined. The easiest way to do this -because you always succed, even with the most complicated curves- is to work with a polynomial equation (2)

$$y = a\varnothing + a1 \cdot x + \cdots + an \cdot x^n \qquad (2)$$

with n + 1 coefficients a∅, a1.....an. The disadvantage of equation (2) is that, almost in any case, the coefficients make no physical sense. It is, therefore, much better to look for mathematically and physically meaningful equations with as few coefficients as possible.

In trying this, two aspects of the progression of the characteristic curves suggest themselves:

a) the curves have to pass through the point F = 0; K = 0: at zero writing force F the contrast K has to be zero

b) as writing force approaches infinity, the contrast should approach a finite value: the most obvious reason is that there is a limited amount of colourformer to be transferred from the capsules to the acceptor-/developer-layer.

In principle this, too, is valid for carbon-copy-papers and, similarly, even for thermal or photographic papers.

The above mentioned aspects call for a regression equation with restrictions (3a) and (3b).

$$K(F) \longrightarrow \emptyset \quad \text{with } F \longrightarrow \emptyset \tag{3a}$$

$$K(F) \longrightarrow K_m \quad \text{with } F \longrightarrow \infty \tag{3b}$$

where F = writing force
K = contrast
Km = maximum achievable contrast

A first indication of the form of the equation is given by computer aided numerical differentiation of the characteristic curves. The result of this is shown in Fig. 5, and everybody will say at once "ah, Gauss". At least, this is what we said, seeing the first computer-drawn graphs.

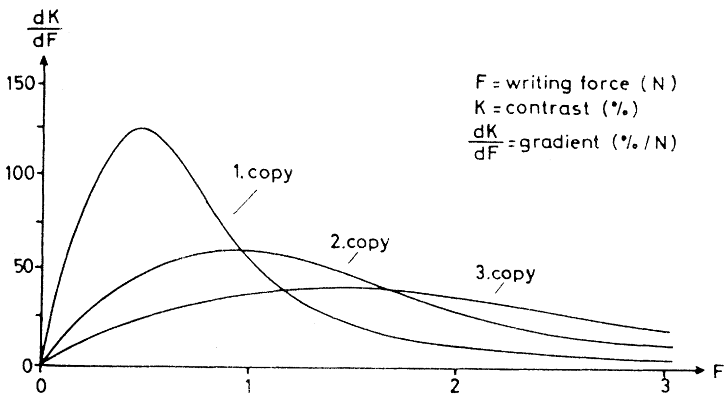


Fig 5—First derivatives of the characteristic curves.

This result was surprising and beautiful and, at the same time, discouraging. It proved that the characteristic curves seemed to be the integrals of normal or perhaps log-normal distributions which can only be calculated by numeric integration.

The consequence of this was to look for a function which would approximate the integral of a normal distribution as good as possible and, at the same time, would have the smallest possible number of coefficients.

A multitude of different formulas has been tested. The best result we obtained -because only three coefficients are necessary - was a $\tan^{-1}$-function as given in equations (6) and (7).

$$y = A \cdot \tan^{-1}(B \cdot x^{C}) \tag{6}$$

$$K(F) = A(cn) \cdot \tan^{-1}\left[B(cn) \cdot F^{C(cn)}\right] \tag{7}$$

where A, B, C resp. A(cn), B(cn), C(cn) = regression coefficients

F = writing force
K = contrast
cn = copy no. (in a multiple set)

Obviously the coefficient A(cn) has the meaning of the maximum attainable contrast Km(cn).

By applying regression analysis to the tabulated values of numerically integrated normal distributions everybody can verify that equation (6) resp. (7) is a very good fitting curve.

The first thing that became obvious when the computer printed the values of the coefficients A, B and C for the particular characteristic curves was the fact that A(cn) proved to be independet of cn, i.e., A(cn) = A = Km = constant for all copies. This finding is quite plausible, because even in a multiple set the contrast must be expected to approach a finite level when the writing force grows towards infinity. It was a first confirmation of the usefulness of equation (7), or to put it in a better way, equation (7) has drawn our attention to a fact which we should have thought about before.

Further computations in regard to the coefficient B and C finally led to the conclusion that they also could be rendered independent of the copy number cn, if a corresponding transformation is applied. That very simple transformation -although only found after numerous trials- is to insert into equation (7) the values of F/nc instead of F, which results in equation (8).

$$K(F_{red.}) = Km \cdot \tan^{-1}(B \cdot F_{red.}^{C}) \tag{8}$$

where Fred = F/cn = writing force F devided by copy number nc.

Fig 6. gives an impression of what happens to the characteristic curves of Fig. 3, when contrast is plotted versus F/cn instead of F alone: there is left one and only one "characteristic curve" (CC), containing all the informations formerly described by a multitude of characteristic curves.

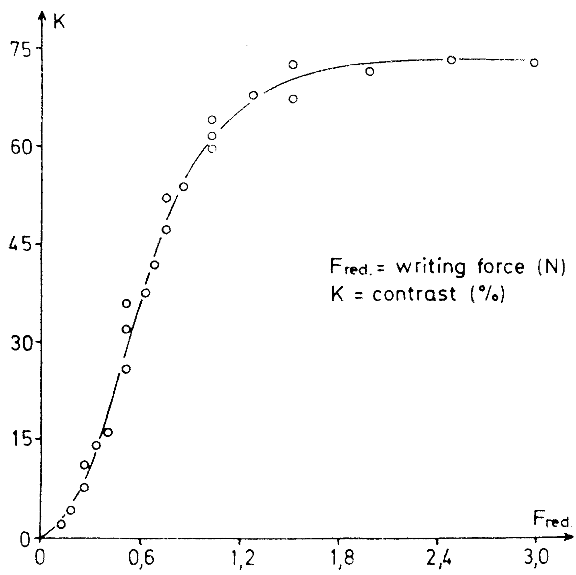


Fig 6—Characteristic curve of PSP.

The physical meaning of the simple transformation $F \rightarrow F/cn$ is that the same contrast will be measured for the first copy at a writing force of 0.5 N and for the fifth copy at a writing force of 2.5 N, a.s.o.

If this is true, it can be seen immediately that the effort of the FM-test can be reduced remarkably. Assuming that six measuring points suffice for exerting regression analysis, then testing at two writing force levels and measuring three copies (at each writing force level) is all that has to be done. Fig. 7 shows the test conditions as we have defined them for our purposes.

writing force F N	copy no. cn	reduced writing force F/cn N	contrast K %
0,5	1	0,5	...
0,5	3	0,17	...
0,5	5	0,1	...
2	1	2,0	...
2	3	0,67	...
2	5	0,4	...

Fig 7—Conditions of the FM-test procedure.

A multitude of PSPs of our own and of competitors have been tested. None ever showed yet equation (8) to be wrong. Indeed, equation (8) also holds true for carbon-copy-papers.

We can't talk about all the numerous investigations we have done. Some of them are

a) dependence on the number of sheets in a multiple set
b) is there a difference between dynamic and quasi-static force impact
c) dependence on the amplitude of the oscillating frequency of the stylus (which means on velocity)
d) influence of stylus frequency
e) which values talk about typewriter/high speed printer suitability
f) why is the CC the integral of a normal distribution

and so on.

Quality criteria from the characteristic curve (CC)

Characterising a PSP by a single CC not only simplifies the test procedure and evaluation but, moreover, also the interpretation of the results. A number of quality criteria (QC) can be derived from proper analyses of the CC. The important QCs have been reported earlier (6). They are summarized in Table 1 and Fig. 8.

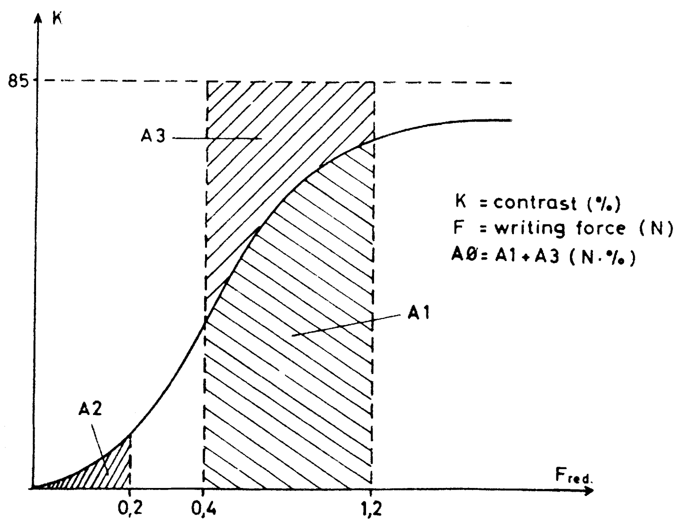


Fig 8—Definition of quality criteria (RØ = area of the dashed rectangle, see Table 1).

symbol	meaning	definition
Km	maximum attainable contrast	upper limit of the contrast
K100	measure for typewriter suitability	contrast at writing force F = 1 N
K50	measure for high speed printer suitability	contrast at F = 0,5 N
D	measure for multiple set suitability	D=(K100-K50)/K100 100
ST	measure for legibility	maximum gradient dK/dF of the characteristic curve CC
A2	measure for tendency towards smudging	area beneath the CC from F=0 to F=0,2N (see Fig. 8)
QF	integral quality measure	QF=A1/A0 100 (see Fig. 8)

Table 1

Definition of the quality criteria (QC)

AN EXPERIMENTAL EXAMPLE

We can't describe here all the details of how and in which direction the QCs depend on the quality of i.e. base paper properties, capsule coating (CB), colour developing coating (CF) a.s.o. Instead, an example discussed in more detail, shall demonstrate the influence of base paper properties on the QC K100. It should make clear how dependences can be studied systematically, if they are based upon the results of a reliable test process.

The base paper properties which we look at are:

a) basis weight
b) density resp. specific volume v
c) thickness

One would expect that these properties influence the performance of a PSP. For the purpose of the investigation handsheets with varying basis weights were produced. Part of them were calendered at nip pressures from 33 daN/cm up to 200 daN/cm, part of them were left uncalendered. After CF- and CB-coating all of them, the FM-test was performed. The resulting main paper properties and the measured K100-values are summarized in Table 2. Papers no. 1 and no. 2 differ slightly in the composition of the base stock.

Applying regression analysis to the values of m_A, v and K100 we arrive at equation (9):

$$K100 = a\emptyset + a1 \cdot m_A + a2 \cdot v + a3 \cdot m_A \cdot v \tag{9}$$

where a0, a1, a2, a3 = regression coefficients.

For papers no. 1 and 2 the regression coefficients are slightly different, as indicated by equations (10) and (11).

$$\text{no.1: } K100 = 71{,}1 + 0{,}1 \cdot m_A + 1{,}43 \cdot v - 0{,}286 \cdot m_A \cdot v \tag{10}$$

$$\text{no.2: } K100 = 74{,}4 + 0{,}1 \cdot m_A + 1{,}63 \cdot v - 0{,}300 \cdot m_A \cdot v \tag{11}$$

Although the coefficients of m_A and v are positive, increasing m_A or v will decrease the value of K100. This can easiliy be seen by differentiating equations (10) and (11) with respect to m_A and v. From equation (10), i.e., there follows

$$\frac{\partial K100}{\partial m_A} = 0{,}1 - 0{,}286 \cdot v \quad < \emptyset \text{ for } v > 0{,}35 \tag{12a}$$

$$\frac{\partial K100}{\partial v} = 1{,}93 - 0{,}286 \cdot m_A \quad < \emptyset \text{ for } m_A > 6{,}75 \tag{12b}$$

paper no.: calendering	m_A g/m²	v cm³/g	$d=m_A \cdot v$ µm	K100 meas. %	K100 calc.(10),(11) %
	43.0	1.675	72	58.4	58.1
1: none	86.2	1.647	142	42.2	42.5
	126.6	1.610	204	29.9	28.8
	43.7	1.350	59	61.9	61.3
1: 33 daN/cm	87.0	1.379	120	45.9	48.3
	126.9	1.348	171	36.9	37.7
	42.5	1.224	52	62.2	62.9
1:200 daN/cm	86.0	1.256	108	53.8	51.4
	126.8	1.245	158	41.0	41.3
1:100 daN/cm	126.4	1.290	163	39.2	39.9
1:2x200 daN/cm	126.9	1.167	148	44.8	44.0
	43.7	1.647	72	59.3	59.9
2: none	87.8	1.650	145	43.9	42.5
	133.1	1.608	214	25.9	26.2
	44.7	1.364	61	62.5	62.8
2: 33 daN/cm	89.4	1.342	120	49.1	49.6
	133.4	1.304	174	36.0	37.8
	44.5	1.258	56	64.0	61.1
2:200 daN/cm	89.3	1.242	111	53.2	52.1
	132.9	1.235	164	41.9	40.6
2:100 daN/cm	132.9	1.264	168	39.2	39.4
2:2x200 daN/cm	133.0	1.167	155	43.3	43.1

Table 2

Data of laboratory CFB-handsheets

In the last column of Table 2 the calculated values from equations (10) resp. (11) are listed. It can be shown that the calculated and measured K100-values correlate with more than 99% significance. Fig. 9 is a threedimensional computergraph of equation (10). It gives a clear picture of the dependence of K100 on m_A and v.

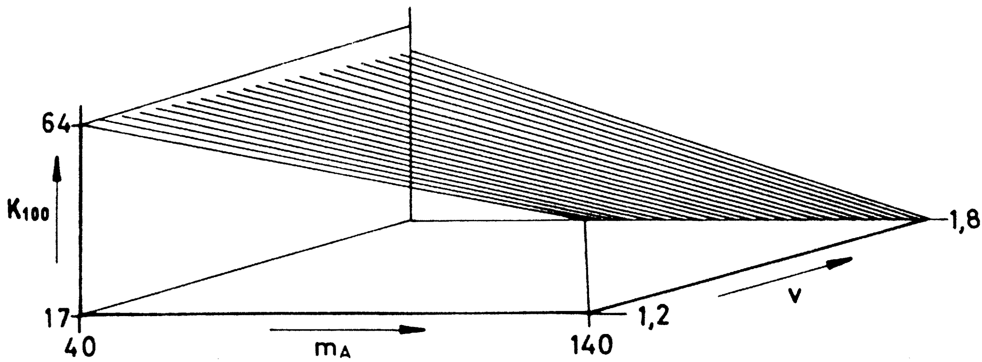


Fig 9—Dependence of K100 on M_A and V (see Table 2)

Comparing papers no. 1 and no. 2 it must be realized that an additional influence -besides m_A and v- leads to differences of the K100-values at equal values of m_A and v, respectivly.

In Table 3 and Fig. 10 the K100-dependence on m_A of the two papers is compared at constant specific volume v. It turns out that paper no. 1 is inferior to paper no. 2 at the same level of basis weight.

m_A	K100 from equ.(10),(11)			
	v = 1,2 cm^3/g		v = 1,8 cm^3/g	
	paper no. 1	paper no. 2	paper no. 1	paper no. 2
g/m^2	%	%	%	%
40	63.7	66.0	58.0	59.7
45	62.5	64.7	55.9	57.5
50	61.3	63.4	53.8	55.3
55	60.0	62.1	51.8	53.1
60	58.5	60.8	49.7	50.9
65	57.6	59.5	47.6	48.7
70	56.4	58.2	45.5	46.5

Table 3

Contrast values from equations (10) and (11)
Comparison at constant specific volume

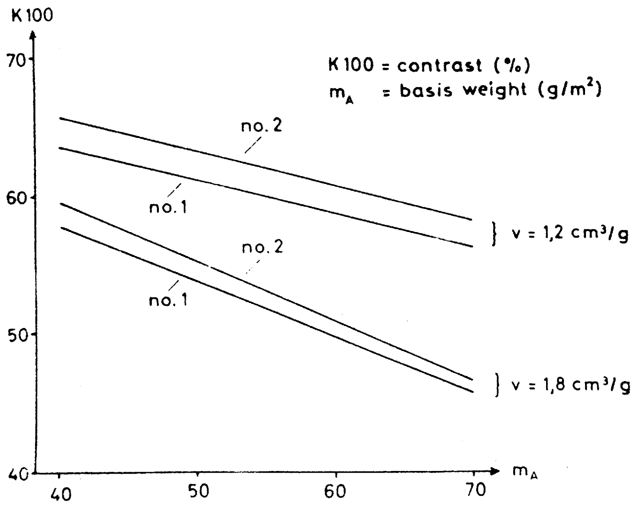


Fig 10—Dependence of K100 on basis weight

A similar result is obtained looking at the K100-dependence on v at constant basis weight m_A (Table 4 and Fig. 11).

v	K100 from equ. (10), (11)			
	$m_A = 40\ g/m^2$		$m_A = 70\ g/m^2$	
	paper no. 1	paper no. 2	paper no. 1	paper no. 2
cm^3/g	%	%	%	%
1.2	63.7	66.0	56.4	58.2
1.3	62.7	64.9	54.6	56.2
1.4	61.8	63.9	52.8	54.3
1.5	60.8	62.8	51.0	52.3
1.6	59.9	61.8	49.2	50.4
1.7	58.9	60.8	47.3	48.5
1.8	58.0	59.7	45.5	46.5

Table 4

Contrast values from equations (10) and (11)
Comparison at constant basis weight

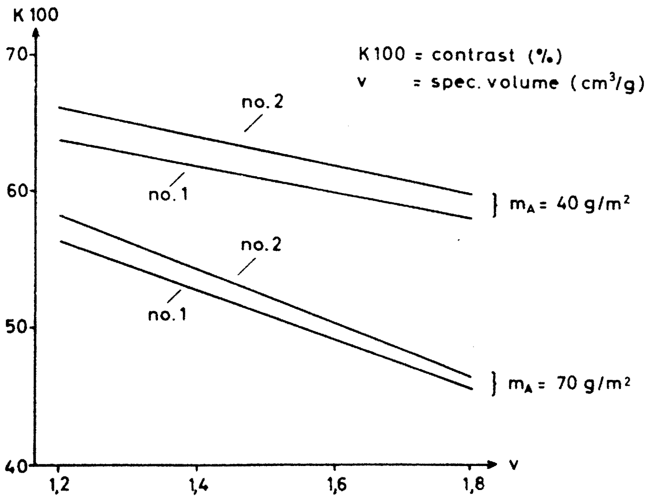


Fig 11—Dependence of K100 on specific volume V.

We suspect the differences in base stock composition to be the causes of this finding, which could indicate that at equal values of v (and m_A) the K100-value is not indifferent to how that v-value is attained. As example, the same v-value is attainable by heavy calendering an ash-free paper, or less calendering a paper with higher ash content. The energy absorption of those two papers can be expected to be different, leading to different effective writing energies and hence to different image densities.

Looking back again to equations (10) and (11) we can discuss the meaning of the m_A- and v-independent coefficients a0 = 71,1 and a0 = 74,4. It is easiliy seen that they are maximum K100-values for vanishing m_A and v. Therefore they should give a measure for the combined quality of the CB-CF-reactivity, eliminating base paper properties. For the two papers the values of a0 should be identical, because the CB- and CF-formulations are. It is difficult to analyse the causes that led to the differences. Perhaps a slightly higher amount of CB-coating may be an explanation. Although paper no. 2 shows -on the average- a 4,4% higher weight, we can't be sure whether this results from base paper or coating weight variation. If it were CB-coating weight, and supposing a linear relationship between CB-coating weight and image intensity -which surely is not correct- multiplying 71.1 by 1.044 results in a value of 74.2 which is remarkably close to that of paper no. 2. The agreement must -for the most part- be regarded as accidental. Nevertheless it is an indication as to how the relationship between CB-coating weight and image intensity can be measured, eliminating influences of the base paper.

In the same way as K100 the other QCs will be analysed. By doing this mutual effects are recognized. This is very important because otherwise one would run the risk of improving a QC at the cost of others.

We believe that the example has shown, how a reliable test can lead to important conclusions, because even small changes in the performance of a PSP and their origins can be analysed.

CONCLUSION

The FM-test represents a simple and rapid means for evaluating the quality and performance of PSPs. The most important results of the procedure are the characteristic curve (CC) and the quality criteria which are derived from the CC.

Very good reproducibility and adjustment of the writing force guarantee the reliable recognition of the relationships between quality criteria and paper properties as well as the influences of operating conditions.

The test has become an indispensible tool for both, development and production control of PSPs.

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APPENDIX 1

Symbols

a0, a1 ..... an	regression coefficents
cn	copy number
d	thickness (µm)
m_A	basis weight (g/m²)
v	specific volume (cm³/g)
x, y	rectangular coordinates
A, B, C	regression coefficients
A2	tendency towards smudging (% N)
D	measure for multiple set suitability (%)
F	writing force (N)
F_{red}	reduced writing force = F/cn (N)
K	contrast (%)
Km	maximum contrast (%)
K100	contrast at F = 1 N (%)
K50	contrast at F = 0,5 N (%)
QF	integral quality measure (%)
R	reflectance of imaged area (%)
RØ	reflectance of nonimaged area (%)
ST	measure of legibilty (%/N)

APPENDIX 2

Abbreviations

CB	coated back
CC	characteristic curve
CF	coated front
CFB	coated front and back
FM	FELDMÜHLE
PSP	pressure sensitive copy paper
QC	quality criteria

Transcription of Discussion

SESSION 5 COATING

Chairman G.A. Baum

Evaluating the Quality of Pressure Sensitive Copy Papers

by D. Horand

Dr. B. Jordan PPRIC, Pointe Claire, Canada

Do I understand you correctly, did you actually measure line acuity and correlate that with the maximum slope of your curve or was your conclusion based on something else? Does your "legibility" measurement exhaust the information in the acuity?

Dr. D. Horand What we did was to take several papers, some of which have been printed using a typewriter and some printed on a high-speed printer and asked a number of people to judge the print quality subjectively and rank their judgement. We then compared that ranking with the steepness of the characteristic curve. The results indicated that legibility appeared to correlate with the steepness of the curve. Does that answer your question?

Jordan Yes, there are several approches to "legibility". I was interested to know whether your conclusions were based on a subjective estimate of legibility or a physical measurement of edge sharpness. Acuity should contain more information than the steepness of your curve. Since you just used subjective ranking, we still do not know whether acuity measurements would be extraneous.

Dr. D. Werthemann Ciba-Geigy, Basel, Switzerland

I have two questions for you. What happens to your characteristic curve when you are measuring the contrast value K, say two hours after printing, twenty-four hours after printing or even several days after printing? I would expect that your Km would vary considerably in such a series. If I am correct, what is your standard time before you measure the K value, and why did you particularly choose that time?

Horand Yes, of course you are right the contrast value will vary with time after printing. The time we normally take is twenty-four hours after printing.

Werthemann How will the B and C values of your regression vary with time?

Horand I would guess that B and C remain virtually constant, while the K value changes.

Werthemann Let me ask the question in a different way. I would suspect that the Km parameter describes the chemistry, whereas the B and C values describe the properties of the capsules and the paper properties.

Horand The values B and C will vary by a small amount according the time after printing but it is the value Km which is the much more significant parameter. This, of course, will change according to the time elapsed since printing.

Prof. K.J. Ebeling Helsinki University of Tech., Finland

My sincere congratulations on a very nice piece of work.

Am I right in thinking, that the functional task is such that structural parameters easily form a critical pair of properties. When you try to increase one property, for example, legibility then you run into difficulties with the other properties, in this case multiple copiability, in other words, these two properties are inversely related to one another.

Horand Yes, you are absolutely right and this is a very difficult problem for us. Moreover, it is not always easy to predict what you may expect from the second property if you make changes to the first one. Obviously, what we are trying to do is to move towards the ideal characteristic curve.

Dr. D. Priest UMIST, Manchester, England

Could you please tell us to what extent you use these procedures for quality control? It seems to me that your standard measuring time of twenty-four hours would be rather too long for that.

Horand We use a similar procedure for quality control measurements but restrict the testing to just the first and third copy rather than carry out the full evaluation which we would use in our research work.

Dr. A.H. Nissan Westvaco, New York, USA

Have you carried out the following experiment determining the curve for the first sheet when it had no backing of other sheets then with two, three, four, five sheets and do you get the same parameters for these as for the single sheet or do you get different contrast values?

Horand Yes, you would expect to see different contrast values depending on the number of sheets in the set. We normally test sets of six sheets but we find that the contrast value for say, five sheets or seven sheets is really not significantly different. You can do it with three sheets but then of course you do not have enough points to construct the characteristic curve.

Chairman

That is related to a question I have. To what extent does your test depend on paper properties?

Horand Well, these are precisely the things we want to look at.

Chairman I was thinking particularly of the Z direction properties.

Horand Yes, our test gives us a very good insight into the role that the structure of the sheet is playing in image formation. Our procedure is very effective at showing up very small structural differences between two otherwise similar papers.

Dr. H.F. Rance Consultant, Beaconsfield, England

This is a comment rather than a question. This is an empirical test which I am sure is of great value in industrial control but if we turn it upside down is it not possible that this could be a very valuable tool for research into the Z direction properties of paper.

Prof. R. Atalla IPC, Appleton, USA

Following on from that, I would have thought that a more informative test from the point of view of research and paper properties would be one in which you have a single line and you do a scan of an image density across it. So, for example, your first scan could show a certain deviation from a square wave and subsequent copies would show greater deviations from that square wave form.

Horand Yes, we have tried doing precisely what you have proposed but in practice it is very difficult to do. You have to appreciate that this line is made up of a series of discrete image points and is not a continuous gradation of image contrast and therefore to obtain useful measurements you have to carry out a large number of scans. For this reason, we do not do it as a matter of routine.

Atalla I would have thought if you could reduce the resolution of the scanning instrument so as to achieve a sort of integrated value you could overcome that problem. Then I should think this sort of measurement could provide you with a very useful indication of how the image was changing in successive layers and thus how the paper properties were contributing to the creation of the image.

Dr. J.S. Aspler PPRIC, Pointe Claire, Canada

Could your procedure be adapted for looking at the abrasion resistance of speciality coated papers? For example, in modern ink jet papers the surface coating is very fragile and very easily abraded and it is extremely difficult, if not impossible, to look at the surface strength properties of these coatings using conventional surface strength tests.

Horand I really couldn't say. We have not used the test for that purpose. We have in fact used it for looking at how fast the colour is fixing in a print. Perhaps I should add that the ballpoint pen which we use in the apparatus must contain ink otherwise the ball will jam and abrade the paper.

Dr. H. Paulapuro FPPRI, Helsinki, Finland

The first derivatives of your characteristic curves resemble log normal distributions. There is a three parameter distribution function called Weibull distribution which has been widely used to describe the types of curve you have obtained. It can be integrated to yield a function corresponding to your regression formulae (6) and (7). Have you tried fitting this distribution function to your data?

Horand No. We have not tried to do that.