

THE EFFECT OF COATING
ON
THE DURABILITY OF BANKNOTES

P. Koeze and A.H.B.Th. van Gelder

De Nederlandsche Bank N.V.
Amsterdam, Netherlands

May 1985
Digitised February 2007

Note

This paper was presented at the Madrid meeting of the Banknote Printers' Conference, 7 – 9 October 1986. This digital version was composed in February 2007 and follows the original text with minor emendations, with the exception of two papers dating from the nineteen fifties which were added to the list of references.

Both authors worked in the Banknotes Technical Development Department of De Nederlandsche Bank N.V., Amsterdam, at the time this paper was published. Dr Peter Koeze retired from the Bank in 2004; Ing Alwin van Gelder is still employed by the Bank in 2007.

E-mail: p.koeze@pkoeze.nl

List of Publications: <http://www.pkoeze.nl/ListOfPublications.pdf>

Curriculum vitae: <http://www.pkoeze.nl/CurriculumVitae.pdf>

De Nederlandsche Bank N.V.

P.O. Box 98

1000 AB Amsterdam

Netherlands

E-mail: info@dnb.nl

Website: <http://www.dnb.nl/>

Summary

The effect of three different coating materials (UMC, CAP and Mowital B3OH) on the durability of Netherlands *f* 25-banknotes has been investigated. Test series with the coatings were produced together with a test series without coating and put into circulation. With the aid of the Bank's sorting system the gradual withdrawal of the banknotes has been continuously recorded for two-and-a-half years from the day of issue. It appears that coated banknotes have a remarkably longer mean time to failure than banknotes without coating. Of the coating materials tested CAP turns out to be superior. On basis of this circulation trial, if CAP-coated banknotes are used instead of uncoated banknotes, only 30% of the number of banknotes needs to be issued in order to keep the circulation at the same quality level.

1 Introduction

The influence of a surface coating on the durability of banknotes has been a controversial point among central banks and their printers. A well-chosen coating material should, in principle, retard the soilage of banknotes while in circulation. In the belief that such an effect is real, Netherlands banknotes are coated since 1957 [1] [2]. Belgium abolished coating after many years of application. Other countries were and are considering coating their banknotes but are not sure if the savings are worth the trouble and the costs to be incurred in the printing works.

As is known [3] [4] [5], De Nederlandsche Bank is able to measure the mean life of banknotes reasonably accurately by means of circulation trials. In 1981 our printing works proposed to test three different materials suitable as a coating and to measure their effect on the durability of Netherlands banknotes. The coating materials were: UMC, CAP and Mowital B3OH. Banknotes coated with UMC were produced in two varieties: one coated with normal layer thickness and one with an extra-thick layer. For comparison, uncoated banknotes were issued also. So, in total 5 varieties of banknotes were issued. The denomination chosen was f 25. The necessary banknote paper was produced and printed as one batch in order to eliminate unintended differences in paper quality. Table 1 summarises the details.

Table 1. Summary of details of the test series. The denomination is f 25.

series	coating	layer thickness (gram/m ²)	number issued	fraction withdrawn at 30-11-84
6757 – 6780	UMC	1.05	297,700	0.7524
6781 – 6804	none	—	297,000	0.9576
6805 – 6828	Mowital B3OH	1.30	294,300	0.7556
6829 – 6852	CAP	1.85	296,600	0.7146
6853 – 6876	UMC extra-thick	1.60	296,300	0.7256

The banknotes were issued in the period from Monday 19 April 1982 to Friday 30 April 1982. In the following evaluation Friday 23 April 1982 is taken as the date of issue. On Friday 30 November 1984, the last day covered by the trial, the notes had been in circulation for 136 weeks and of each variety 70% or more had been withdrawn.

For details of the method of calculation one is referred to the reports mentioned [3] [4] [5].

2 Results

2.1 The return rate

The return rate o is defined as the ratio of the sum of fit banknotes s and unfit banknotes v returned during a week t to the number of banknotes in circulation c at the beginning of week t :

$$o(t) = \frac{s(t) + v(t)}{c(t-1)}. \quad (1)$$

In figure 1 the return rates o of the test series as a function of circulation time t are plotted. For comparison, figure 2 shows the return rate for the entire circulation of the same f 25 denomination. The correlation coefficients between the data sets are given in table 2. As mentioned, all banknotes in circulation (except for the test series issued in this trial) are coated with UMC.

Table 2. Correlation coefficients between the return rates of the test series and the entire f 25 circulation after 136 weeks. Coating 1 = UMC; coating 2 = UMC, extra-thick layer; coating 3 = Mowital B3OH; coating 4 = CAP; coating 5 = no coating; coating 6 = entire f 25 circulation (UMC).

Coating	1	2	3	4	5	6
1	1					
2	0.9654	1				
3	0.9816	0.9688	1			
4	0.9735	0.9875	0.9857	1		
5	0.7029	0.6671	0.7069	0.6615	1	
6	0.7433	0.6729	0.6975	0.6674	0.3909	1

Using the method of least squares straight lines were fitted to the data sets. Under the hypothesis that the slope of the lines is zero the t-statistic has been calculated for a few selected circulation times. The values are shown in figure 3 for the test series coated with UMC and CAP and for the test series without coating. The 0.01 and 0.05 significance levels of the t-statistic are also shown. From figure 3 it is clear that the hypothesis is not rejected for $t \leq 110$ weeks in the case of the test series with coating and for $t \leq 66$ weeks in the case of the test series without coating. Further, the hypothesis that the data sets are independent, normally distributed random variables with equal means has also been tested in the same intervals. That hypothesis is not rejected either. All further results given below are based on those intervals.

Figure 1. Return rates of the test series.

O = UMC; X = UMC, extra-thick layer; H = Mowital B3OH;
 Y = CAP; V = no coating; * = coinciding points.

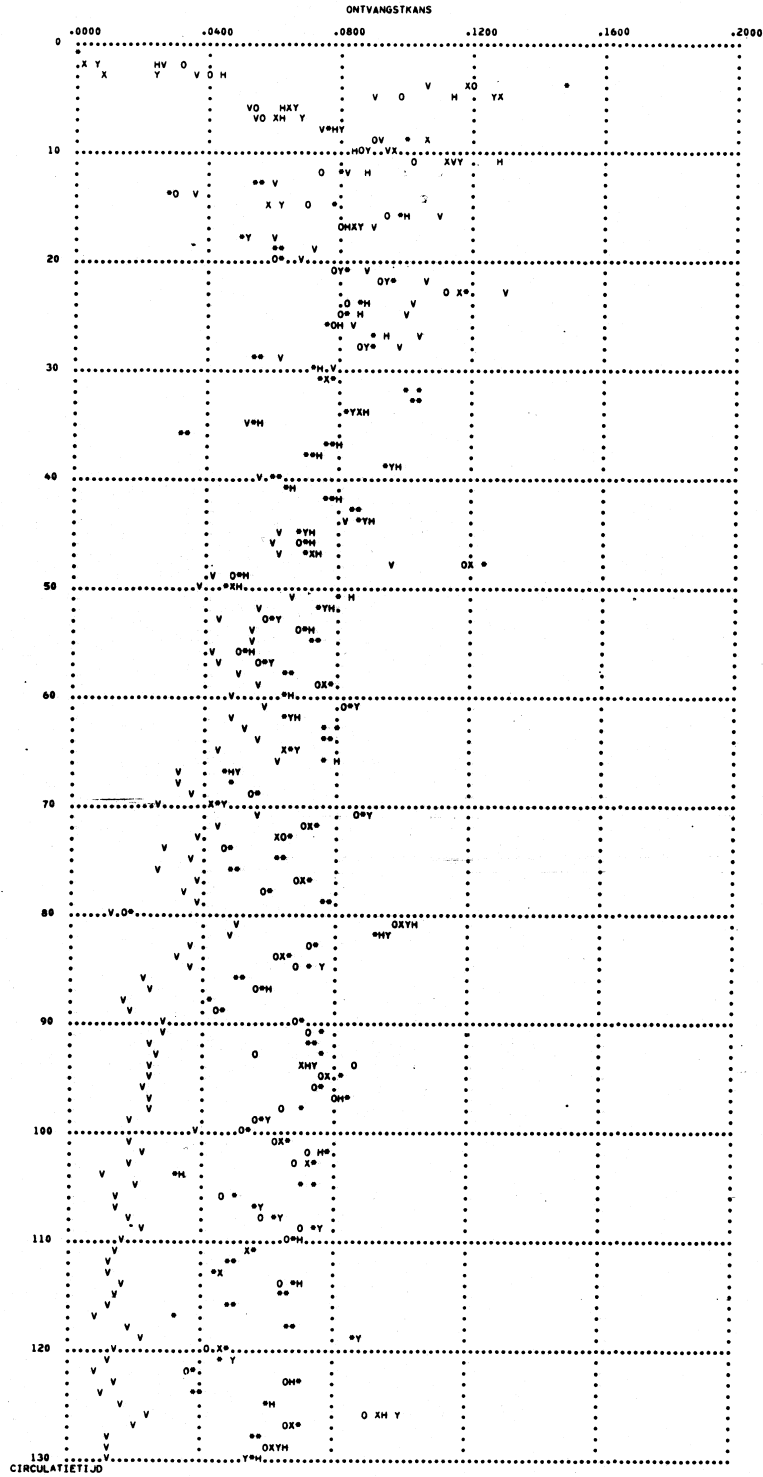


Figure 2. Return rate of the entire f 25 circulation (UMC).

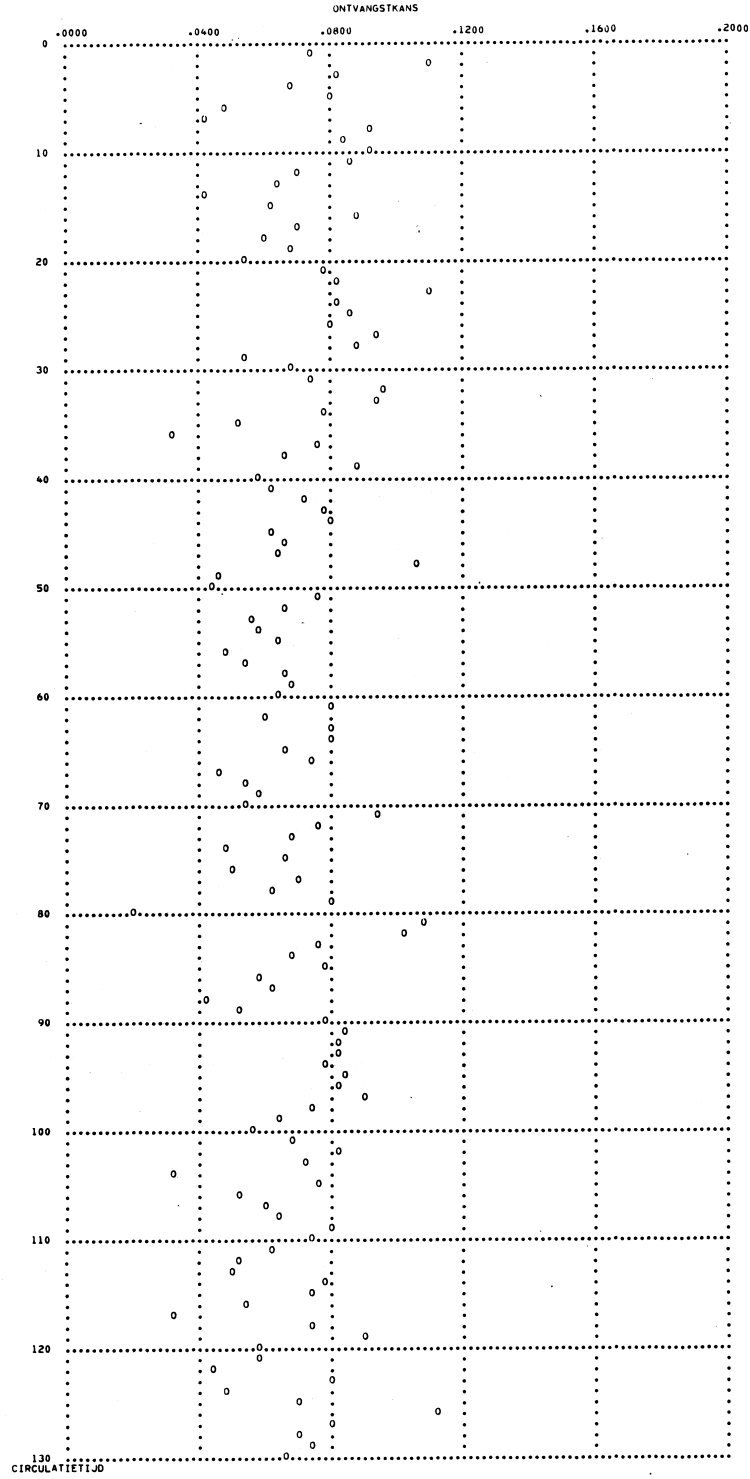
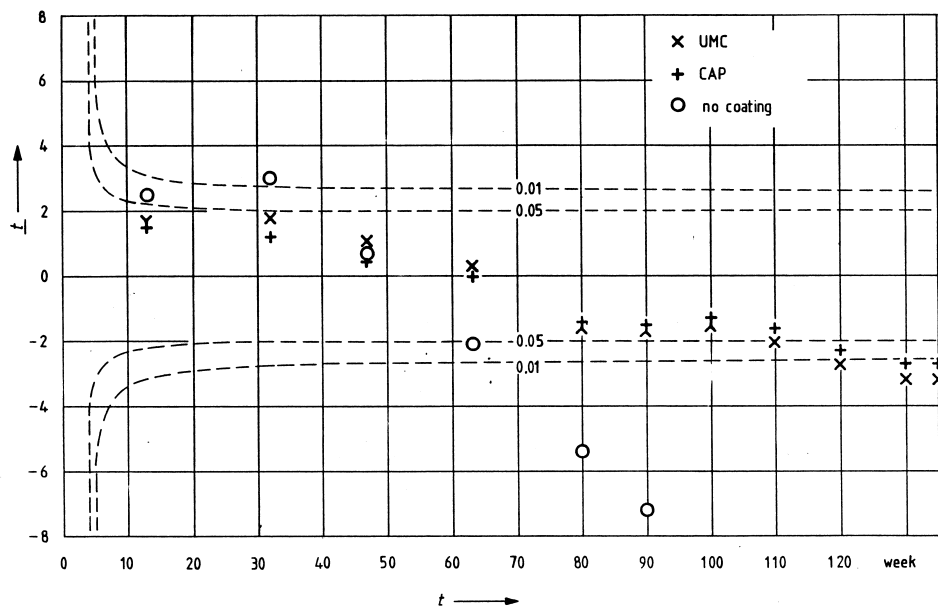


Figure 3. t-statistic of three test series under the hypothesis that the return rate is constant. The 0.01 and 0.05 significance levels are indicated.



The conclusion is that the mean return rates of the test series are equal and constant in the intervals mentioned. The exact values are given in table 3. Beyond those intervals the return rates decrease as a result of cullings and rejects during sorting on the sorting machines [4] [5].

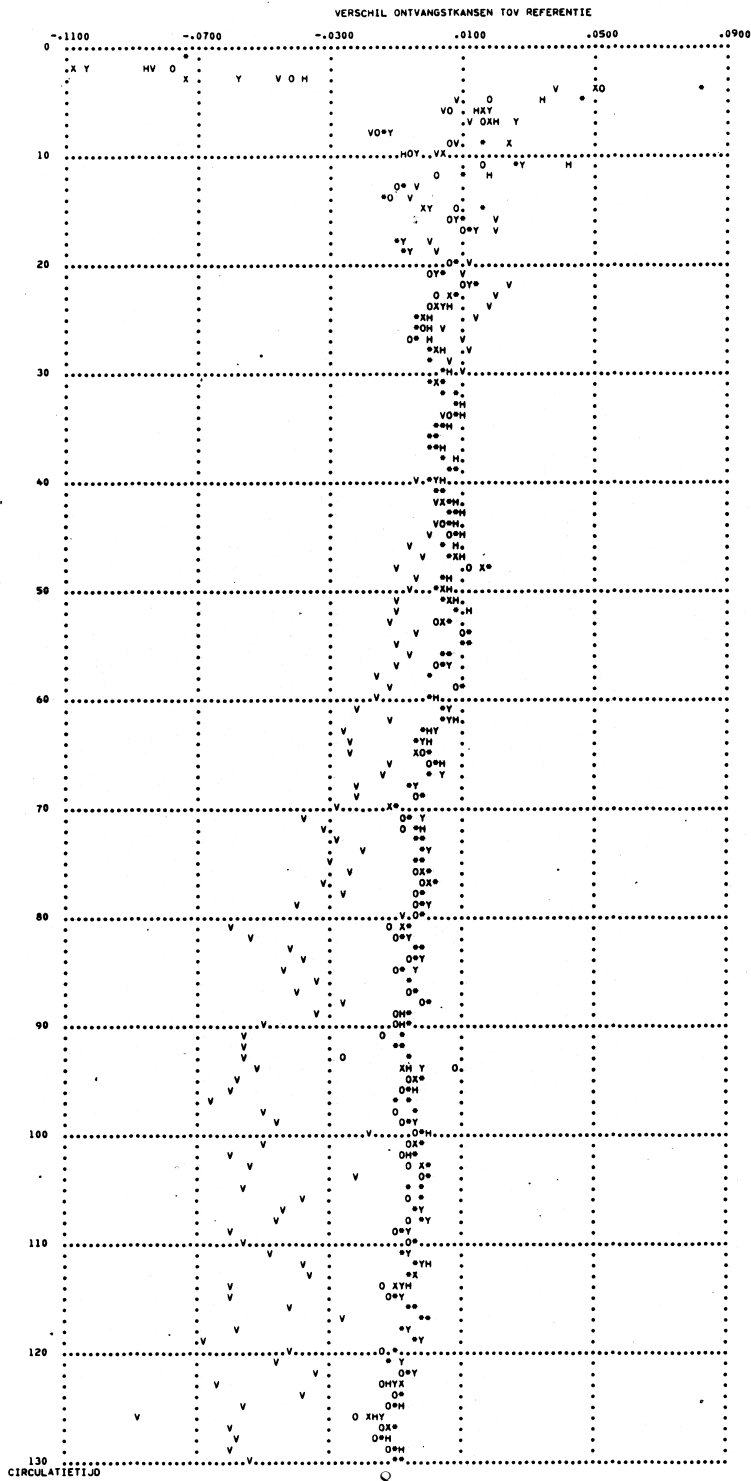
Table 3. Mean return rates of the test series and the entire f 25 circulation

coating	interval (week)	mean return rate (week ⁻¹)
UMC	0 – 110	0.0742
UMC, extra-thick	0 – 110	0.0747
Mowital B3OH	0 – 110	0.0792
CAP	0 – 110	0.0705
no coating	0 – 66	0.0703
f 25 circulation (UMC)	0 – 110	0.0740

Finally, figure 4 shows the difference between the return rates of the test series and the entire f 25 circulation, giving further evidence that the return rates of the test series and the entire circulation are equal in the intervals mentioned.

Figure 4. Difference between the return rates of the test series and of the entire f 25 circulation.

O = UMC; X = UMC, extra-thick layer; H = Mowital B3OH;
 Y = CAP; V = no coating; * = coinciding points.



2.2 The withdrawal rate

The withdrawal rate q is defined as the ratio of the number of unfit notes v to the sum of fit notes s and unfit notes v returned during a week t :

$$q(t) = \frac{v(t)}{s(t) + v(t)}. \quad (2)$$

Figure 5 gives the withdrawal rates of the test series and figure 6 of the entire f 25 circulation. Approximately 80% of the notes without coating against only 25% of the coated notes are withdrawn in the asymptotic case.

Figure 5. Withdrawal rate of the test series.

O = UMC; X = UMC, extra-thick layer; H = Mowital B3OH;
 Y = CAP; V = no coating; * = coinciding points.

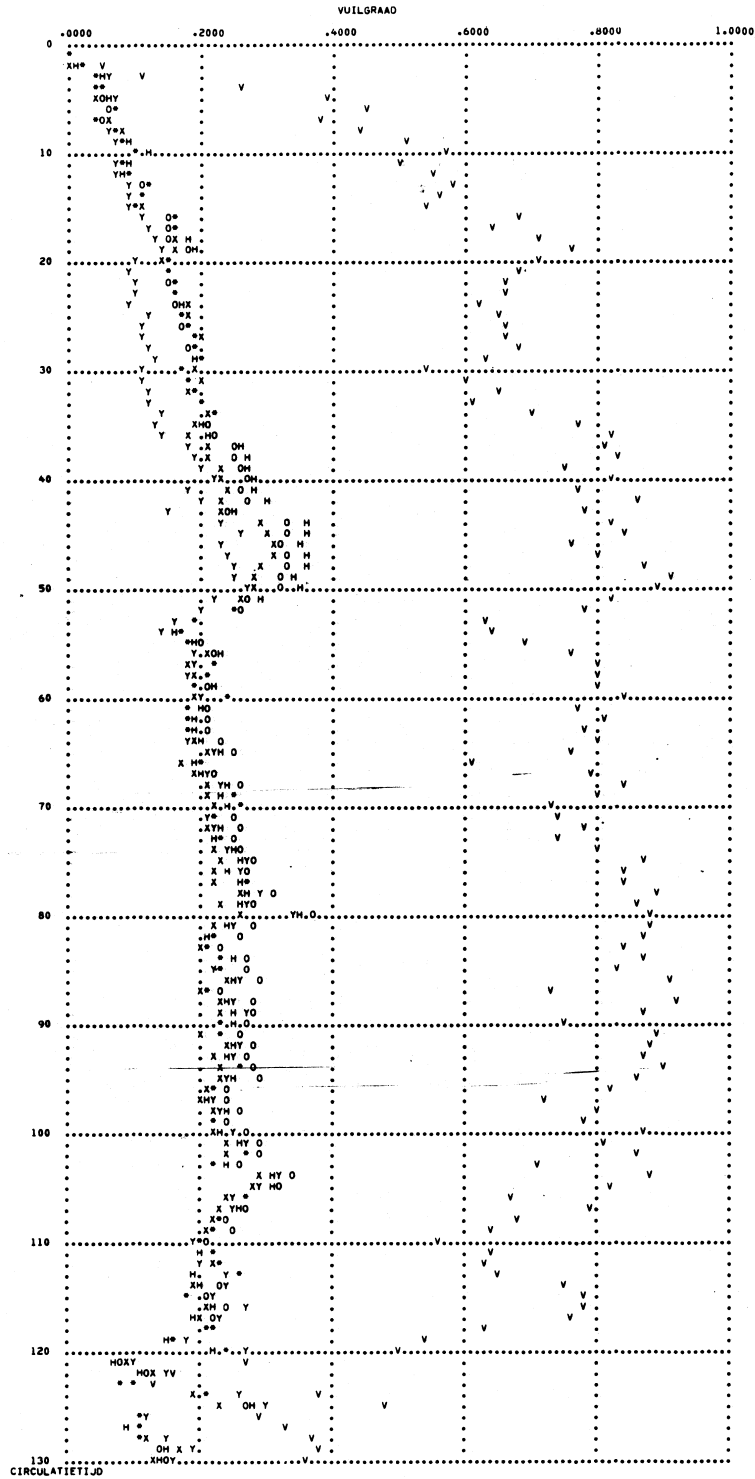
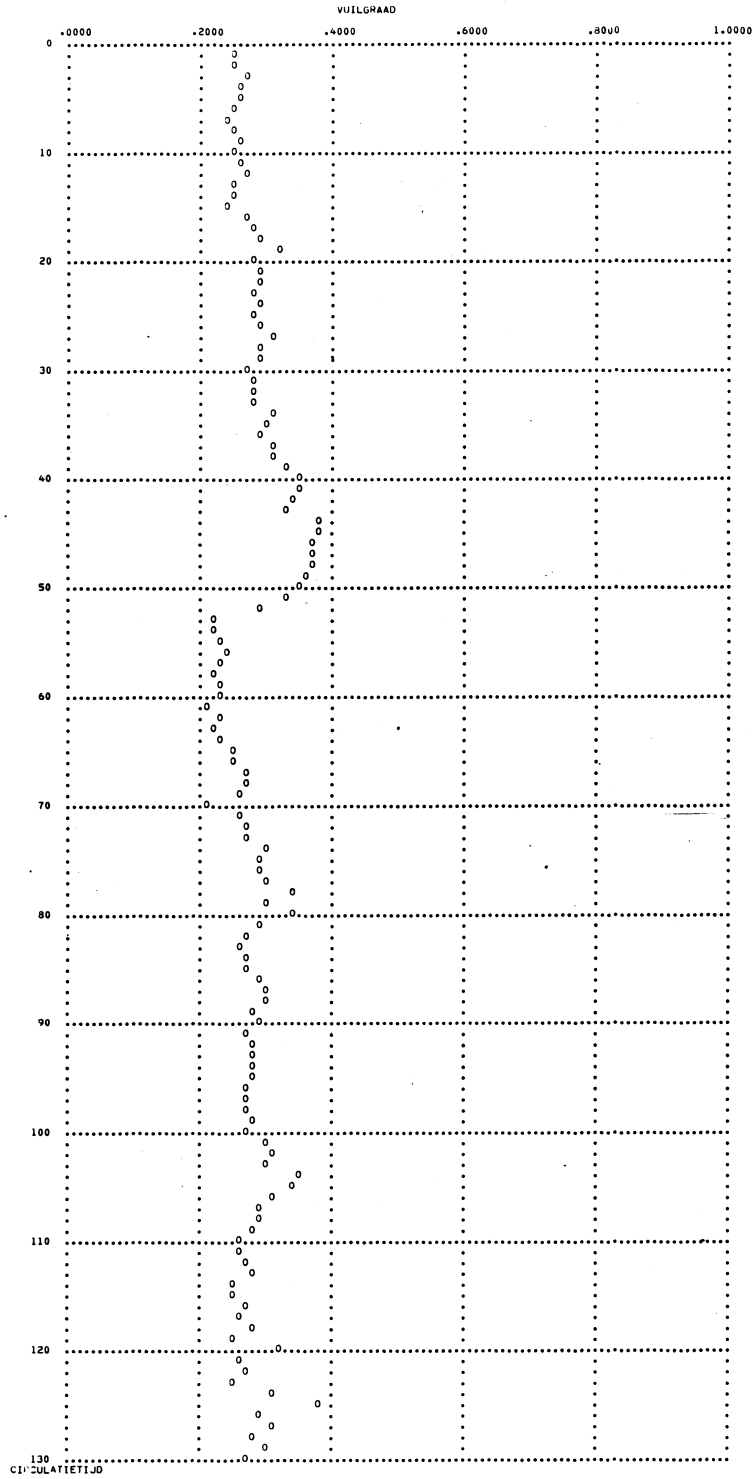


Figure 6. Withdrawal rate of the entire f 25 circulation (UMC).



2.3 The withdrawal curve

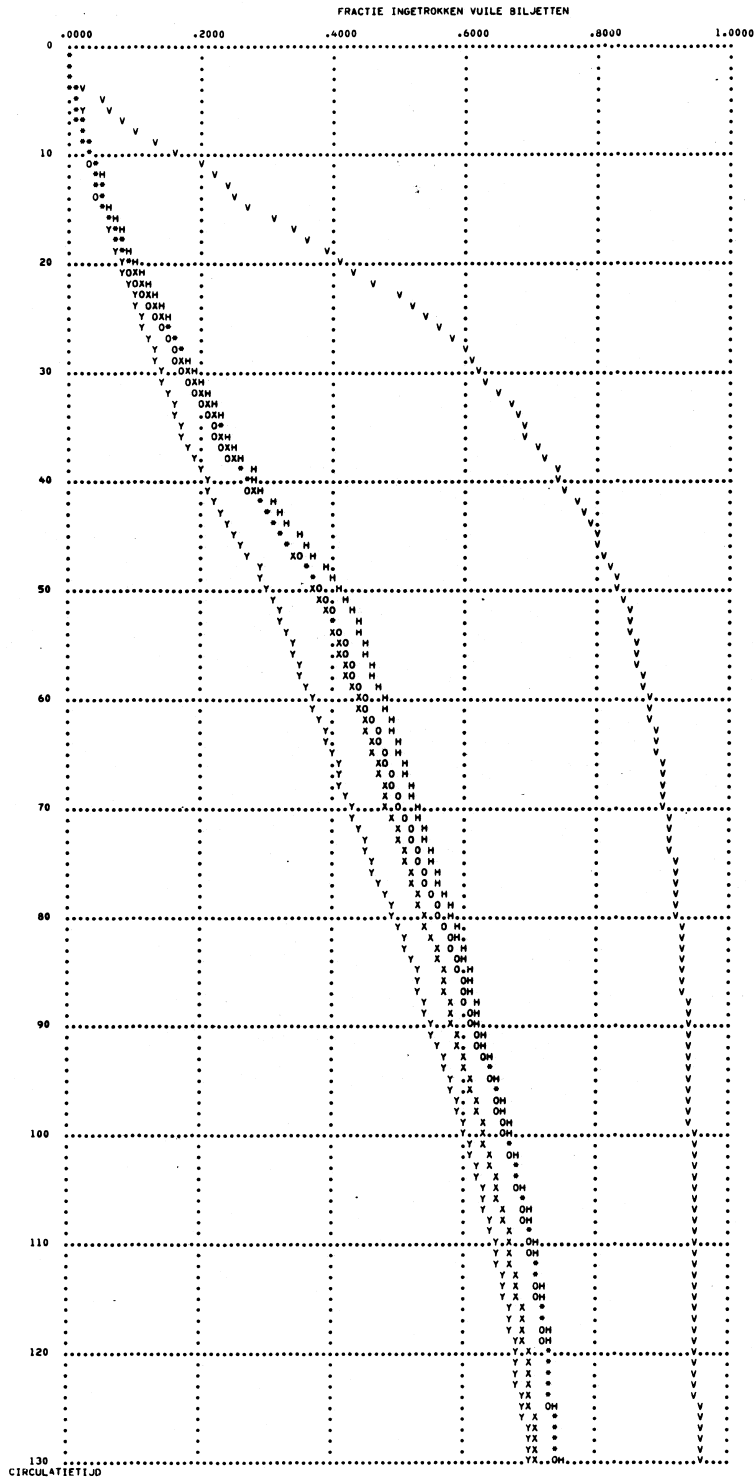
The withdrawal curve is defined as the cumulative fraction of unfit notes as a function of circulation time t . In figure 7 the withdrawal curves of the test series are shown using linear scales. If the withdrawal curve satisfies one of the usual statistical distribution functions, it is possible to calculate the mean time to failure. In the previous circulation trials it was shown that the gamma distribution provides an adequate statistical description. Using the method of Wilk et al. [6] the maximum likelihood parameters of the gamma distribution are estimated as given in table 4. Also given are the resulting mean times to failure.

Table 4. Parameters of the gamma distribution and mean time to failure of the test series.

coating	gamma parameters		mean time
	shape	scale (week ⁻¹)	to failure (week)
UMC	1.97	0.0231	85.5
UMC, extra-thick	1.74	0.0190	91.6
Mowital B3OH	1.84	0.0221	83.3
CAP	1.81	0.0183	99.4
no coating	2.12	0.0707	29.9

Figure 7. Withdrawal curves of the test series.

O = UMC; X = UMC, extra-thick layer; H = Mowital B3OH;
 Y = CAP; V = no coating; * = coinciding points.



3 Discussion of results and conclusions

As shown, coated banknotes have a remarkably longer life than banknotes without coating. Of the coating materials tested in this trial CAP-coating turns out to be superior.

Two effects may account for this result. In the first place new banknotes without coating reflect incident light in a lesser degree than new, coated banknotes: The coating forms a glossy layer on top of the banknotes. That is of influence because the Dutch fitness detectors employ the reflected light intensity as a measure of the degree of soiling of banknotes. Using one of our fitness detectors as a measuring instrument the overall reflection coefficient of new banknotes without coating was determined at 91% of the overall reflection coefficient of new, coated banknotes. We found evidence that a difference in reflection coefficients remains present throughout the life of the banknotes. However, within the attainable accuracy we did not find a difference in reflection coefficients between the coating materials.

The second effect which can explain the longer life is, of course, the sought-for effect of retarding the soilage of banknotes while in circulation. In the laboratory it has been shown that coating in general and CAP-coating in particular on top of banknotes repels a mixture of oil and ink.

Taking the mean times to failure given in table 4 it is easy to calculate potential savings with coated banknotes. If two varieties of banknotes have mean lives $MTTF_1$ and $MTTF_2$, the change-over from variety 1 to variety 2 will lead to a decrease (or increase) of the consumption of notes by

$$100 \cdot (1 - MTTF_1/MTTF_2) \text{ per cent.} \quad (3)$$

Accordingly, issuing banknotes coated with CAP instead of uncoated banknotes should reduce the consumption of banknotes with

$$100 \cdot (1 - 29.9/99.4) = 70\%.$$

In the case of Netherlands banknotes, which are coated with UMC already since 1957, the change from UMC to CAP should reduce the consumption with

$$100 \cdot (1 - 85.5/99.4) = 14\%.$$

References

- [1] N.E. Servatius; ‘The last news about our one guilder notes treated with Ultramid’, *Proceedings Banknote Printers’ Conference*, Helsinki 1955.
- [2] N.E. Servatius; ‘Final conclusions about the series of one-guilder notes treated with Ultramid’, *Proceedings Banknote Printers’ Conference*, Vienna 1956.
- [3] P. Koeze; ‘An accurate statistical estimation of the life-length of f100-banknotes. A circulation trial with two qualities of currency paper’, *Int. Stat. Rev.* **47** (1979) (3) 283–297.
- [4] P. Koeze; ‘The life-length of banknotes. A case study’, *Statistica Neerlandica* **36** (1982) 187–207.
- [5] P. Koeze and A.H.B.Th. van Gelder; *The effect of paper fibre direction on the durability of banknotes*, De Nederlandsche Bank, Amsterdam 1983.
- [6] M.B. Wilk, R. Gnanadesikan and M.J. Huyett; ‘Estimation of parameters of the gamma distribution using order statistics’, *Biometrika* **49** (1962) (3 and 4) 525–545.