Quality marks in banknote design

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1. Introduction

Dutch guilder note designers had a rich tradition of using different kind of marks in their designs. A register mark was used for the proper registration of offset and intaglio print, in addition to cutting marks to check the specified dimensions of the notes. But also other marks were used, e.g. for the visually impaired and ‘stacker marks’ designed to make sure that sorting machine operators to insert the notes properly into the sorting machine. In the last guilder design, a new mark was introduced to prevent colour copying (SC Marks). After the guilder era, new user marks continued to be developed, such as marks denoting the proper feeding direction of a banknote into a banknote acceptor and ‘way finding symbols’. The latter marks served to assist the public in finding the public security features on the banknote.

This paper focuses on quality control marks. Such marks may contribute to good banknote design, as will be illustrated by the historical inventory of such marks in Dutch guilder banknotes. Quality marks may be further developed, as will be presented in a separate ‘take away’ paragraph dealing with the requirements for quality marks in future banknote designs.

The Dutch register marks served the following three purposes, i.e.:
1) enabling the central bank to check each individual note for its tolerances,
2) contributing to the technical complexity of the note (message: hard to counterfeit)
3) allowing easy process-control by printer (no tools required).

Including obvious register marks in a banknote design is not a common design policy. As far as known, no other banknote designs contain such obvious register marks as Dutch banknotes. If marks are used, they are hidden within the design. The argument against obvious marks is that misregistrations would be visible to the public and, consequently, underline the differences between banknotes. Such criticism usually comes from the printer. This is understandable since the printer would like to have as much freedom as possible. And, today, the printer could also argue that quality control of freshly printed banknotes by the central bank could be done at the cashier department using a scanning unit and image analysing software, and that, consequently, quality marks are not required. This was never deemed a valid argument for Dutch banknote designs, since the tolerances were small just as the register marks themselves. The designers of the one but last and the last Dutch banknote series - Robert Oxenaar and Jaap Drupsteen, respectively - both favoured the use of visible quality and other user marks without the use of special aids.

The so-termed ‘landscape model’ also used the banknote’s design as starting point for banknote quality control. To complete the historical overview of quality marks in the NLG banknotes, the landscape model is presented in the annex entitled ‘Quality assurance by DNB’. 
2. Design history of marks in NLG notes

**Summary**
The first register marks were introduced in the NLG 5/Vondel 1, issued on 19 December 1966. These marks already included an intaglio dot within an offset circle. If the register between the two print technologies was within tolerance, the dot would not touch the circle. This was a very successful concept, which was applied for over 30 years!

Cutting marks first appeared in 1968, i.e. on the NLG 10/Frans Hals. This banknote was quite innovative in that it was the first ever to include a mark for the visually impaired and a unique register mark for letterpress and dry offset.

In 1989, two new user marks were introduced: the so-termed BQIS element for an automatic register check and stacker marks for sorting machine operators.

Marks for a Counterfeit Deterrence System were first introduced in 1997, i.e. in the watermark area on both the front and the reverse side of the NLG 10/Kingfisher.

### 2.1 Offset-offset
The first register marks were introduced on the NLG 5/Vondel 1, issued in 1966 (Figure 1). These notes were printed on a Simultan machine using two dry offset plates for the front side and three dry offset plates for the reverse. An intaglio print was superimposed on the offset on the front. This note had register marks for all 5 offset plates, including a see-through register between the front and the reverse. The design of this see-through register was complex and not meant to be used by the general public. The first see-through register meant for the public was introduced in 1986 (oyster catcher on NLG 250/Lighthouse, see Figure 6).

Two years later, a further developed version of the register marks appeared in the NLG 10/Frans Hals (Figure 4). The same design was used for the NLG 100/Michiel de Ruyter (Figure 2) as well as for the other notes of this series. Positioned close to the eyes of the portraits, within the typical ‘television screen’, these register marks were quite obvious.

### 2.2 ‘Offset-intaglio’ register
The first 1966 design of this register mark was slightly changed in 1993. From then on this register consisted of an intaglio circle and an offset dot (instead of intaglio dot and offset circle), the reason being that the intaglio plate had a higher dimensional stability. Within this intaglio circle of Ø 1.5 mm (inner diameter), a dry offset dot of Ø 0.15 mm was printed. Such a mark was also used in the last guilder note, the NLG 10/Kingfisher, issued in 1997.

**Public interest in quality marks**
The Dutch public noticed these new quality control elements. Cartoons and fantasy notes of Dutch guilders often included the ‘television screen’ as a typical design element of guilder notes! (see Figure 3).

The offset circle and the intaglio dot also caught the interest of a clever exhibition designer. Two samples of a 10 guilder note were used: one with the intaglio dot on the left and the other note with the dot on the right (see Figure 4). Looking through stereoscopic glasses, the observer will see a three dimensional image of the note! The notes were on display at ‘Ogen bedrogen’ (‘Eyes fooled’), an exhibition of optical illusions at the Technical University of Delft in September 1983.
Figure 1.
First application of register marks in a Dutch banknote, the NLG 5/Vondel 1, issued on 19 December 1966. The register marks matched on the front:
A: left: offset plate 1 and plate 2 and the intaglio plate (the dot). Right: register between offset plates 1 and 2.
B: left: register between offset plates 3, 4 and 5. Right: see-through register with plates 1 and 2.

Figure 2.
Register marks within so-termed ‘television screen’ in NLG 100/Michiel de Ruyter, issued on 15 December 1972. The register for the offset and the intaglio is located in this ‘technical element’.
Figure 3.
Several cartoons of NLG banknotes in the 1980-1990s, including typical register marks (‘television screen’).

Figure 4.
Creation of stereoscopic image by using two banknotes with maximum tolerance between offset and intaglio print (left-right). People will see a 3D banknote!
Exhibition ‘Ogen bedrogen’ (‘Eyes fooled’), Technical University Delft, September 1983.
2.3 ‘Offset-letterpress’ register

The first register mark offset-letterpress may be found on the NLG 10/Frans Hals, which came into circulation on 4 January 1971. A double concentric circle - for collectors 'bulls' eye' - was printed within offset circles on the reverse side (Figure 5). As this design gave the printer several production problems, after around 5.5 million notes it was abandoned (corresponding with the series 0001-0571) [8].

After almost 20 years, offset-letterpress register marks returned in Dutch banknotes. However, this time no additional letterpress element was introduced, but a number of small support lines. These support lines were printed in offset, facilitating an instant check of the banknote number for correct positioning (the two OCR-B numbers must not touch the lines; see Figure 6). The first note to contain such support lines was the NLG 250/Lighthouse.

Offset register element in NLG 10/Frans Hals. The right-hand section contains a register gauge for offset and letterpress with a double concentric O-sign or ‘bulls’ eye’.

Figure 5.
See-through register for public ‘oyster catcher’

Offset marks in banknote design for checking if the OCR-B numbers are printed at the correct location. A straight object like a ruler is necessary to establish if the numbers are properly aligned.

Figure 6.
To check if both numbers are properly aligned, a straight object like a ruler is needed. This action was frequently performed at DNB’s sorting department at the time of the Toshiba sorting machines (1980-1990s). Why is the note rejected by the number reader? Is the position of the number correct?

Following the introduction of barcodes in 1989, new offset-letterpress marks were designed (see Figure 7). Two small offset angles are printed next to the human-readable number. Horizontally, the barcode should not be positioned too far to the left or the right. The first and last bars should not pass the horizontal line of the offset angle. For the vertical registration, the human-readable figures - which are fixed with the barcode - should not pass below or above the horizontal part of the angle. A ruler or a piece of paper (e.g. another note) is needed to check this alignment.

Figure 7.
‘Offset-letterpress’ register marks in NLG 10/Kingfisher, issued on 1 September 1997.

2.4 Cutting marks

Once all printing steps have been completed, the printed sheets will be cut into notes. There are two basic options for banknote dimension specifications:

1. Specification of the (length) x (width), with a tolerance on both,
   e.g. length = 150 mm +/- 2 mm, width = 72 mm +/- 2 mm.
2. Specification of the tolerance on the cutting position per side,
   e.g. cutting position tolerance per side = +/- 1 mm.

It will be clear that option 2 guarantees a higher quality, as the note’s image will on average be more precisely centred than in the case of option 1. Combining methods 1 and 2 leads to a third option, as is used for the euro banknotes:

3. Specification of the (length) x (width): tolerance of +/- 1 mm and
   specification of the cutting tolerance per side of +/- 1.5 mm.

The guilder notes were cut according to principle 2. Cutting marks were first introduced on the NLG 10/Frans Hals, issued on 4 January 1971 (Figures 8 and 9a).

Once the sheets are cut into notes, each note should show cutting marks on each of its four edges. If they do not, the positions of the cuts are out of specification. The cutting marks are only needed on one side of the banknote, preferably the reverse side. Without any tools being required, these cutting marks will immediately make clear if the note was cut to specifications!
Over the years, different cutting mark designs have been used (Figure 9). The wedge-shaped cutting mark first appeared as a line pattern and later as a solid two-coloured print. In 1986, the wedge shapes were abandoned and the new banknotes were provided with cutting marks printed in just one colour and combined with an offset-offset register (because the NLG 250/Lighthouse passed through the offset press twice!). In 1989, the single-colour cutting marks were provided with two small notches. These notches facilitated the cutter’s job, as they permitted the detection of deviations during the cutting process (stacks of 500 sheets at a time).

Figure 8.
Above: principle of cutting marks: a banknote within a sheet. If the cutting tolerance is e.g. 1 mm for each banknote edge, the width of the cutting marks is 2 mm. The cutting mark length was set at 5 mm. Below left: nominal cut of banknote. Below right: banknote cutting out of position tolerance on the long edges.

Figure 9.
Evolution of cutting marks in NLG banknotes. Dotted line is cutting line.
(a) wedge-shaped cutting mark, first used in NLG 10/ Frans Hals, issued on 4 January 1971.
(b) wedge-shaped ‘solid’ cutting mark NLG 1000/ Spinoza, issued on 15 January 1973.
(c) cutting mark on NLG 250/Lighthouse, including offset register between the first full offset print (5 plates in all) and the second (also 5 plates), issued on 7 January 1986.
(d) cutting mark with small notches as used in NLG 25/ Robin, issued on 27 March 1990.
2.5 Quality element for quality detector

Banknote designer Robert Oxenaar was succeeded by Jaap Drupsteen. In 1989, Mr Durpsteen’s first banknote was issued, the NLG 25/Robin. As Drupsteen regarded the register marks as an enrichment of the note’s design, just as Oxenaar, he copied the offset-intaglio register marks and the cutting marks from the previous designs, besides introducing two new user marks: a quality control mark called BQIS (Banknote Quality Inspection System) and stacker marks.

The BQIS is a system using two components: a special element in the banknote for automated inspection by a simple light detector to be used by the printing works. This element could also be checked by the fitness detector of the banknote sorting machine. Two independent print technologies are out of tolerance if a half moon appears in the register mark, e.g. between offset and intaglio. This is relatively easy to establish. The principle was proposed by Alwin van Gelder (DNB) and is explained in Figure 10. Figure 11 shows the BQIS element in the NLG 25/Robin. Drupsteen combined several ‘technical elements’, including the BQIS and the offset-intaglio register. Just as in the designs of Oxenaar, these ‘technical elements’ are quite obvious and contribute to the desired image of technical complexity of the banknote design.

A special BQIS detector was never developed, also because new image cameras appeared on the market. These cameras could also check the note in transmission.

\[
\begin{align*}
\text{a} &= \text{element printed in technology X (e.g. offset) with circle diameter x (in NLG 25: x = 2 mm)} \\
\text{b} &= \text{full dot printed in technology Y (e.g. intaglio) with diameter (x + 2.t), t denoting the tolerance between the two printing techniques (e.g. offset and intaglio: t = 0.75 mm)} \\
\text{c} &= \text{register between technique X and Y according to specifications} \\
\text{d} &= \text{misregister (the ‘moon’), which is easily detected by state-of-the-art fitness detectors.}
\end{align*}
\]

*Figure 10.* Basic principle of BQIS.

\[\text{Figure 11.} \quad \text{BQIS element first introduced in NLG 25/Robin, issued on 27 March 1989.} \quad \text{Diameter intaglio dot = 3.5 mm. Design: Jaap Drupsteen.}\]
2.6 Stacker marks

With the NLG 25/Robin also the first stacker marks were introduced. Stacker marks, designed for DNB’s sorting machine operators, enabled checking whether banknote packages were fed correctly into the sorting system. The sorting machine generation in use at the time, required that all banknotes to be scanned were fed front and head up. The principle of stacker marks is illustrated in Figure 12. The operator would first look at the short edge of a pile and then place the pile in the stacker of the Toshiba BN500 machine.

![Stacker marks](image)

**Figure 12.**
Above: principle of stacker marks. The marks are positioned a-symmetrically on the short and long edges of the banknote.
Below: four stacker marks on the NLG 25/Robin. The stacker marks on the short edges are combined with the cutting marks.

![A longitudinal view of a typical stack of banknotes](image)
3. Future design requirements for quality marks within a banknote

Which marks are required in today’s banknote design? Customer requirements for such marks should be listed by the central bank (see Table 1 for an overview).

<table>
<thead>
<tr>
<th>MARKS in banknote</th>
<th>USER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Public</td>
</tr>
<tr>
<td>Public security feature marks</td>
<td>●</td>
</tr>
<tr>
<td>Banknote acceptor feeding marks</td>
<td>●</td>
</tr>
<tr>
<td>Denomination marks for the visually impaired</td>
<td>●</td>
</tr>
<tr>
<td>Colour copying prevention marks</td>
<td></td>
</tr>
<tr>
<td>Prevent image software</td>
<td></td>
</tr>
<tr>
<td>Soil measuring marks</td>
<td></td>
</tr>
<tr>
<td>Check correct feeding stacker</td>
<td></td>
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<tr>
<td>QUALITY CONTROL</td>
<td></td>
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<tr>
<td>- Dimension (tolerances, size)</td>
<td>●</td>
</tr>
<tr>
<td>- Colour (tolerances)</td>
<td>●</td>
</tr>
<tr>
<td>- Register</td>
<td>●</td>
</tr>
</tbody>
</table>

Table 1.
Overview of the different users and the corresponding banknote marks.
CDS = Counterfeit Deterrence Systems.
Cash handlers = Professional cash handlers, including equipment.

This paper is confined to covering the quality control marks in banknotes. An overview of the requirements for banknote marks for other users will be presented in a future paper.

The objective is to include clear register marks and measurement areas in the banknote design. These marks may be visible, but should be integrated in the design. The following paragraph provides a systematic list of the quality marks to be considered.

3.1 ‘Watermark-offset’ register marks

The position tolerance of the watermark in a banknote is usually defined as the position tolerance to the rectangular angle of the plain sheet, often set at +/- 3 mm. As far as is known, no banknotes were ever issued with ‘watermark-offset’ register marks. Since the watermark is (the best known) public security feature and the tolerances are - compared to other security features - high, it makes sense to introduce register marks.

Within a single banknote, the place tolerance of the watermark could be related to the first printing step, usually the offset. Since the tolerance of the sheets within the offset printing machine is around +/- 0.5 mm, the position tolerance of the watermark to the offset print is +/- 3.5 mm. Today, the offset Super Simultan press uses up to 4 offset plates per side. The first plate from each side (plates 1 and 5) is often taken as the offset reference.

Figure 13 shows the basic principle for position checking of watermark-offset register marks. The marks are printed preferably by offset plate 5 on the reverse side - just one side will suffice - and the watermark must not touch these little support lines.
Figure 13.
Basic principle to check the specified position of the watermark by using 4 support lines printed in offset. The support lines are positioned on the ‘largest watermark bulges’. In the nominal position, the watermark is 3.5 mm away from the 4 offset lines. In no banknote must the watermark touch the printed offset lines. For this feature, the reverse side is preferred.

3.2 ‘Offset-offset’ register marks (on one side)

The tolerance between 3 or 4 offset plates on one printing side of the Simultan press is small. A typical specification is +/- 0.05 mm from one offset plate to the reference offset plate (e.g. plate 1 for the front side and plate 5 for the reverse). To design a visible register mark for such small values is not easy. Since the error range of measurements with a glass ruler is of the same magnitude as these small tolerances, special marks should be designed. Printer Enschedé developed such a mark for DNB/ECB in 2001, based on the principle that lines must not touch each other (Figure 14).

Figure 14.
Plate 1 = blue (= reference), plate 2 = yellow and plate 3 = orange.

3.3 ‘Offset front-offset reverse’ register

The tolerance between the offset print on the front and the offset print on the reverse side is small, typically +/- 0.10 mm.
For many years, this ‘perfect’ match between the front and the reverse was not possible for other, commercially available presses (although some satisfied this specification). Therefore, this register was used as a public security feature: the see-through register. As, today, counterfeits often have good registrations between front and reverse, the feature is no longer strong. A quality mark could be used instead of a public see-through design (see Figure 15).
Figure 15.
Example of ‘offset front and offset reverse’ register. Solid offset dot on the front and a complementary circle on the reverse side. The value proposed for A is 5 mm and could be combined with the solid offset measurement (see section 3.5).
Instead of two circles, two squares could be used. A square would facilitate measuring the deviation (see misregister on the right).

3.4 Offset dimensions: triangular measurement

Offset printing is sensitive to small distortions. To check if the dimensions of the offset images are correctly printed so-termed ‘triangle measurements’ could be performed. To facilitate such measurements, three marks could be printed in one offset plate, using a small cross. For optimal distortion measurements the triangle should be as large as possible and therefore these marks should located at the banknote’s edges (see Figure 16).

Figure 16.
Any distortions or deviations of a printed image may be checked with a triangle measurement. Position the marks on the note’s edges, two on the short edges for optimal measurement accuracy.
Left, above: three measurement marks for triangle measurement of a printed image.
Left, below: the triangle. Each line is specified, e.g. a = 150.08 mm, b = 54.64 mm and c = 178.45 mm.
Right: example of letterpress register mark combined with a triangle measurement mark.
3.5 Solid offset measurement

After the register and dimensions, the colour specifications of the offset inks used could be checked. For such colour measurements, the note must contain a circular area large enough for the measurement spot of a spectrophotometer or densitometer. These spots may vary in diameter from about 3.5 mm to 9 mm. A diameter of 5 mm will provide a solid basis for such colorimetric measurements. Since offset inks are transparent, lab values might be unreliable. Instead, density measurements could be performed, as practised on the colour bars of a printed sheet.

Theoretically, every (offset) ink used should be measured. However, as this would require 10 or even more measuring spots on each side of the banknote, this seems impracticable. Instead, one or two marks could be introduced of the most critical inks. The spot may be located at any place, but the other side should by all means preferably have a homogeneous background. Neither should the location of the spot contain other interfering inks, while the reverse of that location should be unprinted or in solid offset. The element could be combined with the offset front-back register, described in section 3.3 (see Figure 17).

![Quality mark example](image)

Figure 17.
Example of a quality mark for colour measurements with a spectrophotometer: a solid area (offset).

3.6 Register marks for ‘continuous stripes’

Register marks for stripes are all based on the same principle: create two ‘offset support marks’ in the design. The movement of the feature or printed element should stay within these marks.

3.6.1 Offset-security thread
The security thread is part of the paper. The security thread has a so-termed ‘wandering zone’ to avoid cockled paper stacks. A typical value for the wandering zone is a movement of 6 mm, both to the left and to the right side of the nominal position of thread. Two small offset support lines might be printed by plate 5 on the reverse side of the note. The thread should stay within these lines (see Figure 18a).

3.6.2 ‘Offset-silk screen’ register marks
The register between the offset (plate 1 or plate 5) and a silkscreen print is typically set at +/- 1.5 mm. The position of a silkscreen band will wander only in the cross or horizontal direction. The band should not touch the small offset lines as indicated in Figure 18b.

3.6.3 ‘Offset-foil stripe’ register marks
The register between the offset (plate 1 or plate 5) and a foil print is typically set at +/- 2 mm. In case of a foil stripe there is only a tolerance in the horizontal direction. The band should not touch the small offset lines as indicated in Figure 18c.
Figure 18.
Register marks for three ‘continuous stripe’ security features based on the same principle: two small offset support lines are printed to verify the maximum locations of the feature. Also other designs could be made to mark the maximum positions.

3.9 ‘Offset-intaglio’ register mark

The register of the intaglio print to the offset reference printing plate (plate 1) is typically set at +/- 0.75 mm. The register is constructed of a small intaglio circle with an inner diameter of 1.5 mm and an offset dot with a diameter of 0.15 mm. The line width of the intaglio circle is 0.15 mm. The intaglio-offset register is still within specifications if the offset dot touches the intaglio circle line (see Figure 19).

Figure 19.
Left: dimensions of offset-intaglio register.
Middle: principle of offset-intaglio register. A small offset dot should always be inside the circle printed in intaglio.
Right: intaglio not in register with offset.
3.10 Register marks offset-letterpress

The register between the letterpress and the offset is typically set at +/- 1.5 mm in both machine and cross direction. Small support lines are printed close to the number to check the position and the alignment. The offset support lines should be printed in the offset reference plate of the reverse side (plate 5). See Figure 20 for the basic design principles of these register marks.

![Figure 20](image)

Basic design principles of offset supporting lines to check the position and the alignment of the two numbers on a banknote.

3.11 Plain paper and/or soil measurement

To verify the paper tint each banknote should have an unprinted area with a diameter of at least 5 mm. This area should not be part of the watermark (but it could be), and not have any print on the other side (see Figure 21). In principle, the colour could be measured in reflection and in transmission (although a method for the latter is not yet available). Additionally, this spot may also be used for fitness checks on notes in circulation. Central banks and third parties may measure the soiling of the banknote on the basis of the ‘grey level’ of this spot, like the ‘dust bag indicator’ on your vacuum cleaner.

![Figure 23](image)

Schematic presentation of an unprinted area within the banknote design for plain paper measurements, which could also be used as a ‘soil level indicator’. Minimum diameter 5 mm.
5. Conclusions

5.1 The introduction of special marks in banknotes should be based on an analysis of the user requirements.

5.2 Quality marks - like print register marks - and also other user marks - like stacker marks - contribute to good banknote design and the image of technical complexity. While these marks, as such need not be obscured from the general public, they should not attract too much attention either.

5.3 Register marks enable verification of a banknote’s printing tolerances at any time and without any tools. Therefore - even with a 100 % automatic quality control on single finished banknotes - quality marks in each single banknote are useful to the central bank and third parties, for example, when verifying cash handling equipment.

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APPENDIX
Quality assurance by DNB

From its very foundation 1814, DNB was required to develop ‘Quality Management Systems’ for banknotes, since DNB has always been independent from Joh. Enschedé, the printing works from which it procured its banknotes.

The register marks in the NLG notes - introduced in 1966 - became part of the incoming banknotes’ quality control check at the central bank (section ‘Creation Check’). The ‘dot in the circle’ was used for scanning packages of notes (so-termed ‘filming’).

In the 1980s, the quality inspection of new banknotes was - in line with the time spirit - further developed into a Quality Assurance model. In 1992, DNB presented this model to the Paper Committee of the Banknote Printers’ Conference in Burgos (see Figure 1 [2]). The Quality Assurance Model was an integral approach from the cradle to the grave: from the R&D for new banknotes to the destruction of unfit banknotes. The approach focused on quality checks of semi-finished products - ‘at the source’ - and on process verification. Today, this model is still in use, although some activities may have been renamed. The ‘inspection regulation for circulated banknotes’, for example, is now set by the Eurosystem and is referred to as ‘the framework’ [9]. Also a Programme of Requirements for new banknotes was part of the Quality Management System (QMS) [10].

ISO certification
DNB has always strived for a reliable and efficient QMS, but never applied for an official ISO 9001 accreditation for its quality management of banknote development and production. DNB does have an ISO 9001 accreditation for its sorting department, though. In 2007, the banknote sorting department of DNB received its first ISO 14001 certificate (environmental management system).

Paper specifications
Barring a few exceptions, DNB always used to purchase the banknote paper for printer Enschedé. This was highly uncommon, as central banks normally leave the procurement of banknote paper to the printing works. With the introduction of the euro banknotes, the market for banknote procurement became more transparent. Euro banknotes may be ordered from over 14 different printing works and at least 9 paper mills are able to produce the euro banknote paper. To become in line with others - and with a keen eye on a future tendering process – in 2007 DNB decided to leave the banknote paper procurement to the printer. The paper specifications are still a separate chapter and pass from the central bank via the printing works to the paper mill.

AQL procedure
DNB’s approach to quality was to check a specification just once and as early as possible in the production process. When the new notes were delivered to DNB, a final Quality Acceptance procedure was performed on the basis of samples. This AQL method (Acceptable Quality Level) defined the risks of both the supplier and the client [1].

Defining quality
If you visited a printing works in the 1980-1990s, you would probably see large displays of banknote misprints, which were meant to familiarise the workers with the quality criteria. Other printing works would create files containing all kinds of printed samples. Also, in many cases, only one complete set is displayed, safely locked up by the supervisor. The disadvantage of each of the above instructional methods is that the banknote specimens are not easily accessible and that they cannot cover all possible misprints.

In 1992, your author came up with the idea to describe the quality in a more generic way and to make a practical, visual instruction for all workers involved. This model is called the ‘landscape model’ (see Figures 1 and 2 and Table 1). The method, which was developed in close cooperation with DNB’s printer Enschedé (Mr. Co Lemmers), relates allowable printing flaws to areas within the banknote. In 1995, the method was implemented for all NLG-denominations [3, 4, 5, 6, 7].

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Both the printers at the presses and the printers’ quality department used these instructions. At DNB, the same documents were used to verify the delivered notes on their printing quality. Shortly after the issuance of the euro banknotes in 2002, the European Central Bank adopted this method for the quality control of euro banknotes, renaming it ‘Zoning Model’. This model was also further optimised with, for example, the introduction of a ‘fibre’ as printing error.

100 % single note inspection
Up to the year 2000, the quality inspection of new banknotes at Enschedé used to be performed by the human eye. Complete printed sheets were manually checked for defects by female workers. In 1999, with the start of the euro banknote production, DNB insisted on the introduction of 100 % single note inspection using modern cameras and image analysing software. This policy was in line with the ECB’s policy to set the technical specifications for the final product and not for the plain paper sheets or progressive printing stages of euro banknotes.

Incoming quality inspection at DNB ended with the introduction of the euro. Instead, DNB started to verify product quality at the premises of the printer. The acceptance procedure is based on batches or lots of 4 million banknotes. From these batches, the automated quality inspection system randomly selects 500 banknotes, 20 of which are verified for compliance with specifications by measurements. The other 480 banknotes are visually checked. Still, on each incoming lot of 4 million banknotes a gross-error check is performed by processing a sample on DNB’s sorting machines.
Figure 1.
Overview of the Quality Assurance Process undergone by banknotes of the Nederlandsche Bank in the 1980-1990s [2].

* = including origination and several proof prints and zero production run
** = including re-circulation by third parties (under supervision of central bank)
Figure 2.
Example of a banknote representation according to the ‘landscape model’ or ‘zoning model’ [6].
Above: NLG 25/Robin, front.
Below: NLG 25/Robin, reverse.

- Little holes
- ‘Hickies’
- Stains

< 1.5 mm

< 1.5 mm

< 1.5 mm

- Little hole or fluff
- Bite or ‘hicky’
- Stain

Figure 3.
Definition of holes, bites and stains for quality control of NLG notes.

<table>
<thead>
<tr>
<th>Allowed printing errors in area</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little holes</td>
<td>1 1 2</td>
</tr>
<tr>
<td>‘Hickies’</td>
<td>0 1 2</td>
</tr>
<tr>
<td>Stains</td>
<td>1 2 3</td>
</tr>
<tr>
<td>Maximum</td>
<td>2 4 7</td>
</tr>
</tbody>
</table>

Table 1.
Printing quality defined by the allowable number of printing errors. In case of the NLG notes, the same table was used for both the front and the reverse side of the note.
References

1. De Heij, H.A.M.; 'Tolerances in design and mass production of banknotes’, De Nederlandsche Bank NV, Banknote Printers’ Conference/Paper Committee Meeting, Oslo 30 - 31 May 1989
9. ‘Recycling of euro banknotes: framework for the detection of counterfeits and fitness sorting by credit institutions and other professional cash handlers’, European Central Bank, Frankfurt January 2005

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