The Nederlandsche Bank and banknotes
INTRODUCTION

Mechanical sorting of Netherlands banknotes started as early as 1971 with the arrival of one Crosfield sorting machine. In 1975 manual counting and sorting came to an end and was fully taken over by mechanical sorting on Crosfield sorting machines.

For a new, second generation of banknote sorting machines the Nederlandsche Bank started a market survey in 1980. In the event, an integrated information system was developed based on Toshiba banknote sorting machines. Today 18 automated banknote processing systems are operational with a total capacity of one milliard banknotes a year.

Banknotes and sorting machines have to be compatible. For the purpose of automated sorting, Netherlands banknotes had not only to be changed to a uniform height of around 75 mm, but also had to incorporate special security features for automated detection of counterfeits.

This brochure provides information on the 'know why' of both the design of Netherlands banknotes and the new banknote processing systems. It also supplies the technical specifications of the latter.

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- Banknotes as an industrial product
- Sorting banknotes
Banknotes in the Netherlands

The Netherlands, as at 1 January 1992

Population 15.13 million
Currency unit Nederlandse Gulden (NLG)
Exchange rate NLG 1 = ECU 0.43697
Circulation value NLG 37.3 milliard ECU 16.3 milliard
Notes in circulation 351.5 million
Average number of notes 23 per inhabitant
Cash dispensers 0.3 per 1000 inhabitants
Average counterfeits accepted by the public 7.5 notes per million

The head office of the Nederlandsche Bank is located in Amsterdam. Twelve agencies are efficiently spread over the country.

The local branches of the commercial banks obtain the required currency daily from the agencies. On average each note in circulation returns 2.8 times a year to the central bank. This system guarantees rapid circulation and permits the continuous monitoring of the quality of banknotes.

All banknotes received at the agencies are faced and edged by commercial banks. From the agencies the banknotes are frequently transported to the head office in Amsterdam. There, the banknotes returned from circulation are processed centrally using Banknote Processing Systems.
Banknotes as an industrial product

Product overview (1 January 1992)

<table>
<thead>
<tr>
<th>Denomination</th>
<th>Design</th>
<th>First day in circulation</th>
<th>Numbers in %</th>
<th>Value in %</th>
<th>Life (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NLG 1000</td>
<td>Front</td>
<td>15 Jan. 1973</td>
<td>4.4</td>
<td>41.6</td>
<td>6.7</td>
</tr>
<tr>
<td>ECU 436.9</td>
<td>Reverse</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NLG 250</td>
<td>Front</td>
<td>7 Jan. 1986</td>
<td>4.8</td>
<td>11.4</td>
<td>5.0</td>
</tr>
<tr>
<td>ECU 109.2</td>
<td>Reverse</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NLG 100</td>
<td>Front</td>
<td>16 Mar. 1981</td>
<td>38.7</td>
<td>36.3</td>
<td>3.2</td>
</tr>
<tr>
<td>ECU 43.7</td>
<td>Reverse</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NLG 50</td>
<td>Front</td>
<td>7 Sep. 1982</td>
<td>8.5</td>
<td>4.0</td>
<td>1.0</td>
</tr>
<tr>
<td>ECU 21.8</td>
<td>Reverse</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NLG 25</td>
<td>Front</td>
<td>27 Mar. 1990</td>
<td>19.2</td>
<td>4.5</td>
<td>1.2</td>
</tr>
<tr>
<td>ECU 10.9</td>
<td>Reverse</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NLG 10</td>
<td>Front</td>
<td>4 Jan. 1971</td>
<td>20.9 + 20.9</td>
<td>96.5 + 2.0</td>
<td>1.3</td>
</tr>
<tr>
<td>ECU 4.4</td>
<td>Reverse</td>
<td></td>
<td></td>
<td>99.8</td>
<td></td>
</tr>
<tr>
<td>Million notes</td>
<td></td>
<td></td>
<td>351</td>
<td>NLG 37.3 Milliard</td>
<td></td>
</tr>
</tbody>
</table>

Life is defined according to the BPC formula:

\[
\text{Life} = \frac{(\text{last year's notes in circulation}) + (\text{this year's notes in circulation})}{(\text{this year's new notes issued}) + (\text{this year's notes withdrawn})}
\]

In 1988 the NLG 5/Vondel note was replaced by a coin. There are still some of these NLG 5 notes in circulation. In 1990 a new series of banknotes was introduced. The NLG 25/Robin is the first note of this new series.

Product development

The design for note series is chosen on the basis of a design contest. The models are developed one by one and are also issued one by one. Basically, once every two years a new model is issued. Therefore, a series of 6 denominations is renewed once every 12-15 years. This permits new techniques to be implemented.
quickly and ensures feedback on issued notes.

This strategy also has logistical and production advantages. Research and development (R&D) has to evolve new security features for incorporation in new notes. The design philosophy is based on the notion that the value of a note must be easily recognized. Secondly, the public must be able to check the (public) security features. Because the public remembers realistic pictures more easily than abstract ones, the public security features in recent notes have been designed as realistic pictures. All other elements in the new series are abstract.

Product development of new banknotes and processing system is organised by means of project management.

CONSUMER RESEARCH

Information from customers is essential for good product design. A simple and effective method is used to obtain market information. Once every two years the knowledge and the appreciation of the latest notes are measured. This is an objective way of ensuring feedback as to the quality of the latest banknote designs. Most important results are:

- correlation between the appreciation of a banknote (beautiful or ugly) and the knowledge about picture and text elements
- nobody knows more than four security features in 1991 the average number of security features known to a Dutchman is 1.43. This is slowly increasing over time; in 1983 the number was 1.16.

CIRCULATION TRIALS

With the aid of the Number Reading System specific series of banknotes can be monitored in circulation. One specification in an experimental series is changed, after which the life is compared with the life of standard notes. Research in 1987 showed that varnished notes have a longer life than unvarnished notes. DAR-varnish (Dirt and Abrasion Resistant coating on cellulose basis) has been applied since and has increased the life of banknotes by almost 15%.

In another circulation trial no difference was found in life between notes with different directions of the cotton fibres (long-grain as opposed to short-grain notes).
Security features of banknotes

The security features in the banknotes are designed for different users:

1. GENERAL PUBLIC
   Typical of public security features is that they can be checked without the aid of a tool or instrument. Nor is it necessary to compare the note with another one. The features are explicitly mentioned on the latest model NLG 25/Robin!

2. CASHIERS AND BANKNOTE AUTOMATION
   Because cashiers usually check a note in their workplace, they can use tools and instruments such as an uv-lamp, a magnifying glass or a filter. In addition to the public features, a cashier may use four more security features. In banknote automation banknotes are also used and checked in the same place.

Cash dispensers are important in banknote automation

1. Watermark
2. Tactile ink
3. See-through register
4. Microlettering
   For the public micro-lettering we use a letter height of 0.3 mm.
The Netherlands notes have three security features that are checked by the central bank:

- watermark in paper
- intaglio pattern
- unique banknote number

Banknote production facilities

PAPER MANUFACTURER
VHP Security papermill
P.O. Box 648
7300 AP Apeldoorn

PRINTING WORKS
Joh. Enschedé & Zonen
Bankbiljettenruckkerij BV
P.O. Box 114
2000 AC Haarlem
Sorting Banknotes

After circulation all banknotes are returned to the head office. The notes are automatically counted, sorted into fit and unfit notes and checked for counterfeits. Over the last 10 years the Nederlandsche Bank has developed a unique banknote processing system offering many advantages. It enables, if so desired, the dispersion of the sorting machines over the branch offices while retaining the possibility of central data processing. Other objectives are:

- modular design of independent components with a view to optimization of each component
- distributed intelligence and local decision algorithm for rapid processing
- self diagnostics in detection systems for technical feedback
- production feedback for operators and management

Contractors

Five engineers of the Bank managed the development of the new sorting system, to which a large number of contractors contributed. The most important were:

- Toshiba, Tokyo
- TNO/TPD Institute of Applied Physics, Delft
- HAS Automation Systems, Amsterdam
- Nedinsco, Venlo
- BSO, Utrecht
- TNO Product Centre, Delft
- Digital Equipment, Utrecht
- Objecta, Houten
- Polychromal, Alkmaar

View of Banknote Processing System
### HISTORY

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>prototype</td>
</tr>
<tr>
<td>1986</td>
<td>first series of 4 sets</td>
</tr>
<tr>
<td>1988</td>
<td>additional 4 sets</td>
</tr>
<tr>
<td>1989</td>
<td>additional 5 sets</td>
</tr>
<tr>
<td>1990</td>
<td>last 4 sets</td>
</tr>
</tbody>
</table>

Currently in operation: 18 sets

### Specifications of the Banknote Processing System

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing costs per 1000 sorted banknotes (sorting operation only)</td>
<td>NLG 15 (ECU 6.6)</td>
</tr>
<tr>
<td>Banknote sorting machine</td>
<td>Toshiba BN 300</td>
</tr>
<tr>
<td>Production capacity</td>
<td>35,000 per hour average quality notes</td>
</tr>
<tr>
<td></td>
<td>30,000 per hour poor quality notes</td>
</tr>
<tr>
<td>Production hours</td>
<td>8:15 - 16:45</td>
</tr>
<tr>
<td>Number of operators per system</td>
<td>1.25 (5 in a unit of 4 machines)</td>
</tr>
<tr>
<td>Notes sorted in 1991</td>
<td>935 million</td>
</tr>
<tr>
<td>Linear transportation speed of notes</td>
<td>4 m/s</td>
</tr>
<tr>
<td>Final reject rate of notes</td>
<td>0.3 per 1000</td>
</tr>
<tr>
<td>MTBF</td>
<td>200 hours</td>
</tr>
<tr>
<td>MTTR</td>
<td>0.5 hours</td>
</tr>
<tr>
<td>Noise level (1 m, 1.50 m height)</td>
<td>74 dB (A)</td>
</tr>
<tr>
<td>Counting accuracy</td>
<td>0.01 counting error per 100 million</td>
</tr>
<tr>
<td>Security detectors: 1 paper</td>
<td>watermark detection system AQUIS</td>
</tr>
<tr>
<td></td>
<td>Intaglio Scanning And Recognition Device ISARD</td>
</tr>
<tr>
<td></td>
<td>Barcode Reading system BCR and OCR-B number reader system OCR</td>
</tr>
<tr>
<td></td>
<td>2 printing</td>
</tr>
<tr>
<td></td>
<td>3 number</td>
</tr>
<tr>
<td>Sliprate for counterfeit notes</td>
<td>01 per milliard</td>
</tr>
<tr>
<td>Reject rate for genuine notes</td>
<td>01 per 1000</td>
</tr>
<tr>
<td>Fitness detector</td>
<td>Banknote Fitness Inspection System BFIS</td>
</tr>
<tr>
<td>Average number of fit notes</td>
<td>80 %</td>
</tr>
<tr>
<td>Average number of unfit notes</td>
<td>20 %</td>
</tr>
</tbody>
</table>
Floor layout

Modular thinking enabled the creation of independent working units of four sorting machines each. A working unit consists of seven persons: one unit supervisor, one technician and five operators. Quality of work is improved by:
- good social relations (low noise level, good ergonomics, eye contact)
- constancy in terms of staffing, for instance one technician for one wing
- constancy in terms of customers, a wing knows for which branch office they work
- enlarged cycle time by reducing the frequency of the same motions
- enlarged tasks of the operators, including simple maintenance
- increased involvement through offering feedback about production figures or counterfeited notes

SECURITY

The working areas are marked by optimal security as the result of:
- well-defined areas for operators (four sectors in a wing)
- well-defined areas for units (colour of the floor)
- transparency, limited hiding spots, transparent boxes
- limited human contact with banknotes
- 4-eyes principle (operators face each other, unit supervisor circulates in the unit)
- standard working volumes (batches of 10,000 banknotes)
- efficient administration

OUTPUT AND STACKING UNIT

For neat and temporary storage of the processed packages of 100 notes an output and stacking unit was developed in 1989. The unit handles the output flow while allowing the operator to continue input work, and conversely.
**Computer Control Systems**

Several computers are used in the banknote processing system. They constitute a hierarchical system and are linked together by ETHERNET.

**MCC**

Maintenance and Communications Computer
This computer system tops the computer network. The functions of the MCC are:

- collection and presentation of management information
- on-line production information
- fitness rate per denomination or model
- auditing information
- machine performance and technical condition
- central control of sorting parameters
- collection of banknote numbers of circulated notes for the off-line Number Registration System

**DGC**

Data Gather Computer
This system is the intermediate link between the actual banknote sorting machine and the MCC. Data from the SPCs are selected, concentrated and temporarily stored in the DGC. A few times a day these data are upstreamed to the MCC. The DGC also functions as a host for the group of sorting systems assigned to it. The performance information on four machines is presented to the supervisor.

**SPC**

Sorting Process Computer
The SPC controls the banknote sorting machine using the data from the detectors. It also keeps independent count of the number of processed banknotes and accounts for operations. The operator communicates with the SPC by means of a terminal.
Banknote detection systems

Four detectors have been developed: one fitness detector and three authenticity detectors. All detectors can be adjusted for optimal performance. Model parameters can be implemented and monitored with the aid of software of the MCC.

Design drawing BFIS

FITNESS DETECTION

The BFIS (Banknote Fitness Inspection System) has been one of the major development projects of the Bank in cooperation with the TNO/TPD Institute of Applied Physics. The BFIS provides the economic rationale for the Banknote Processing System. The BFIS digitizes the reflected image of the front of the banknote into approximately 3000 pixels of 2.0 mm x 1.8 mm and checks for:

- overall dirt, soil
- local dirt, stains, writing, reflecting adhesive tape
- missing pieces, incomplete notes
- tears and holes
- folded corners

Tuning of the BFIS model parameters is empirically determined and can be monitored on-line. The very first prototype was build in 1978.
COUNTING

The Toshiba BN 500 has an electronic counting system based on 9 double built sensors. These sensors monitor a note through the sorting machine. This counting system has a very high counting accuracy: less than 1 counting error per 100 million notes.

Multiple feed detection
The high counting accuracy is partly due to the mechanical multiple feed detector. This detector signals if two or more notes stick to each other.

COUNTERFEIT DETECTION

Netherlands banknotes contain special machine detectable features in the paper and ink. These features are used only by the sorting machines of the Nederlandsche Bank.

1 Paper (on-line)
The AQUA watermark reading System (AQUS) uses transmitted light to check for the presence of a special watermark in the banknote paper. This watermark is formed during the production process of the paper.

The watermark may be overprinted and hence be invisible for the public. The AQUS system has been developed for the Bank by the TNO/TPD Institute of Applied Physics. The prototype dates from 1981.

2 Intaglio printing (on-line)
The Intaglio Scanning And Recognition Device (ISARD) uses reflected light to check for the presence of intaglio printing on the banknote. The intaglio pattern allows a high degree of design freedom. This detector was also developed by the Bank in cooperation with the TNO/TPD Institute of Applied Physics. The first prototype was built in 1971.
Banknote number reading (on-line)

All Netherlands banknotes are uniquely identified by a number, which takes the form of either two identical OCR-B numbers or a single barcode. The Bank started OCR-B number reading on new and circulated banknotes in 1968. All new models carry a single barcode. The code and the matching reading system are a further development of commercially available knowledge and equipment by the Bank and HAS Automation Systems. This BCR-detector is highly reliable. The performance is less than one reading error per milliard notes! Other advantages are that the BCR is cheap and the printed barcode in the note offers a great design freedom.

The barcode integrates a denomination and model code as well as a 9-digit banknote identification. It is also possible to add a country code! The BCR prototype was available in 1987. The banknote numbers are processed in an off-line Number Registration System for various purposes.

DESTRUCTION

All notes that have been found unfit are destroyed in a Kusters granulating and compacting machine. The destroyed notes are returned to Joh. Enschedé as fuel for power generation.

Kusters Engineering BV
P.O. Box 230
5900 AE Venlo