

New Banknotes: From Concept to Circulation

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A core function of the Reserve Bank is to maintain public confidence in Australia's banknotes as a secure method of payment and store of wealth. To meet this objective, the Reserve Bank has been developing a new banknote series to upgrade the security of Australia's banknotes. The process has involved integrating artistic designs that reflect Australia's cultural identity with a range of complex technical features designed to make the banknotes very difficult to counterfeit. This article outlines the various steps of the process of 'banknotisation' for the new banknote series, whereby the design concept is developed into a finished banknote.

Introduction

Australia has a tradition of developing and introducing technologically advanced security features for banknotes. One example was the use of polymer as the production material (or substrate) for banknotes in the late 1980s. This was an innovative approach to create substantially more secure banknotes, which were much harder to replicate convincingly than the first generation of paper decimal banknotes. Australia's first polymer banknote – a commemorative \$10 banknote celebrating Australia's bicentenary – was issued in 1988. It served as a trial for the new substrate and featured a clear window containing an image that moved when the banknote was tilted (an optically variable device or hologram) as a security feature. This was followed by a complete series of Australian banknotes printed on polymer – a world first – introduced between 1992 and 1996, which continue to be used today.

The security of polymer banknotes has ensured that Australia's counterfeiting levels have remained relatively low over the past 20 years, particularly compared with international experience (Kim and Turton 2014). But the increasing availability of high-quality, low-cost graphic reproduction technology has also made Australia's first series of polymer banknotes more vulnerable to

counterfeiting. Mindful of this increasing threat, the Reserve Bank had been researching new anti-counterfeiting technologies for a number of years and, in 2007, formalised this work by establishing the Next Generation Banknote program. The purpose of the program was to upgrade the security of Australia's banknotes to ensure that they continue to be secure against counterfeiting. The program was announced in 2012 and the first denomination – the new \$5 banknote – was issued into circulation on 1 September 2016.

The process of designing and producing a new banknote is extremely complex. Extensive research and development is required to assess potential security features and to transform design concepts into functional banknotes. Together with the selection of innovative features that ensure the new banknotes will be secure against counterfeiting, the development of the narrative elements of the overall design is particularly important given the role banknotes play in reflecting Australia's cultural identity. This article describes the process of selecting of security features, creating design concepts and testing the designs to make sure that the banknotes can be printed effectively and efficiently at the required volume, and that they will be durable when issued into circulation.

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Design

The primary objective of the program is to upgrade the security of Australia's banknotes to ensure that they remain very secure, while maintaining many of the familiar features of the first polymer banknote series. The design challenge has been to maximise the security of the banknote, subject to constraints of space on the banknotes and production capabilities.

There are two key elements to the design process: the selection and design of security features; and the development of design concepts for the banknote bringing together the security features and narrative elements. Much of this work is undertaken in parallel and, therefore, results in a number of iterations in the design of the layout of the security features and the narrative elements.

Security features

Since increasing security was the primary objective, the first step in the design process was the selection of suitable security features. A survey of potential features was undertaken, including features already in use around the world and those newly released or in development. This generated a list of around 200 potential features, many of which had been commonly used on paper banknotes and some of which were unique to polymer. These features were assessed by the Reserve Bank on the basis of four key criteria:

- Resilience to counterfeiting
 - (a) difficulty of creating a reproduction that effectively mimics the feature
 - (b) ease of use to validate banknotes by the public and equipment (such as vending and ticketing machines)
- Resistance to damage in circulation
- Manufacturing considerations
 - (a) ability to produce the banknote to required quality standards
 - (b) cost of production

- Ability to integrate with each other and the design to produce additional, more complex security features.

The most important factor to consider in the selection process was the extent to which a feature would meet the primary objective of increasing the banknotes' resilience to counterfeiting. This assessment had two parts: how difficult it would be to counterfeit the feature; and how easily the feature could be used to verify whether a banknote is genuine. A feature that was very easy to use for verification but equally easy to counterfeit would not provide a significant increase in the security of a banknote. Conversely, if a feature was extremely difficult to mimic but also very difficult for the public and machines to use to validate a banknote, it may be ignored by the counterfeiter and the public, thereby adding little value to a security upgrade program.

The landscape in which banknotes need to function today is very different from the environment into which the first polymer series was released in 1992, when machine-based processing, verification and dispensing was not as widespread. In developing the new series, it was necessary to ensure that a range of machine-readable security features were included that would enable efficient use of, and reliable authentication by, machines. A banknote design that could not be effectively dispensed by automated teller machines, or readily accepted in vending and ticketing machines or self-service check-outs, would not provide the functionality expected by the public.

The next issue to consider was how resistant to damage each security feature would be in circulation. This is an important factor for an issuing authority because a feature with poor durability cannot be reliably used to verify a banknote and introduces additional costs associated with replacing worn and damaged banknotes.

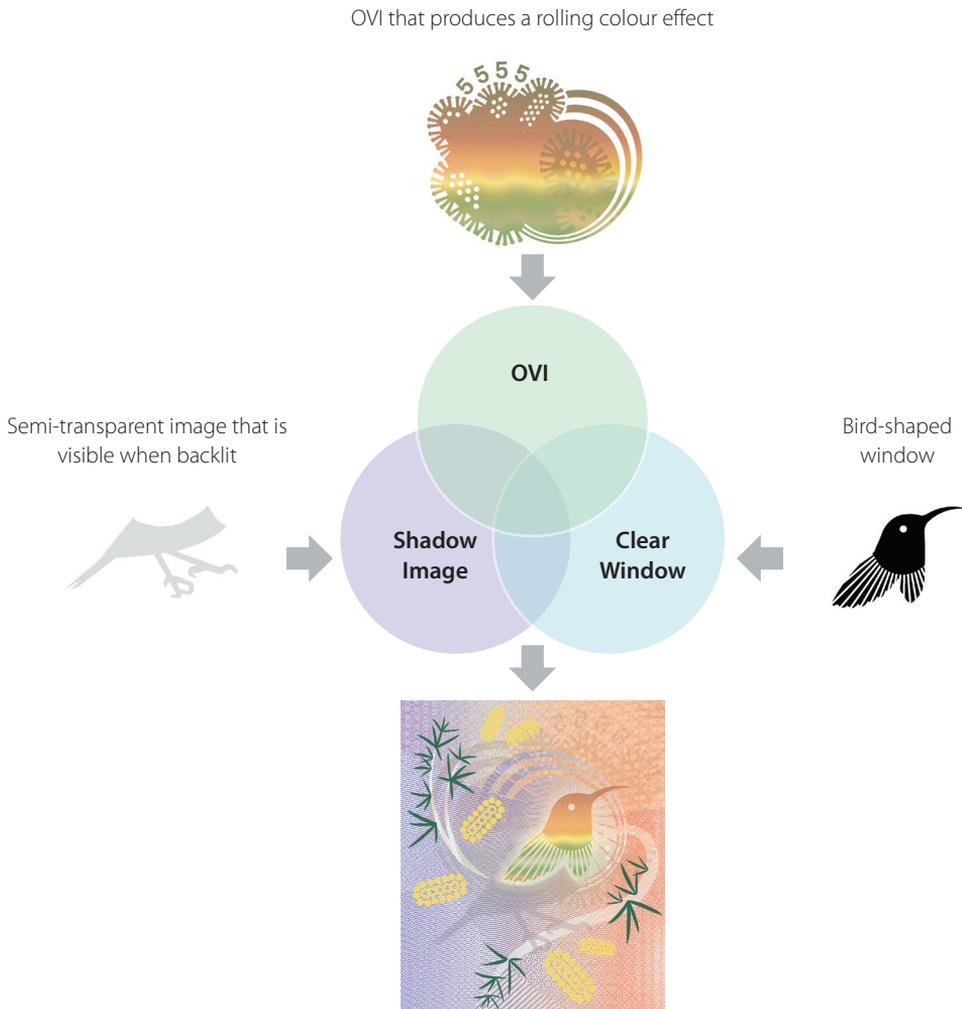
Manufacturing considerations were also important. From a production perspective, it is important that the feature can be produced at high quality and consistency. While the cost of production also

needs to be reasonable, it is important to recognise that using readily available and low-cost materials and equipment is generally not conducive to a highly secure feature as it would also make it easier for a counterfeiter to mimic. A complex manufacturing process that uses specialist materials and techniques introduces significant barriers to a would-be counterfeiter. Importantly though, while necessary, manufacturing complexity does not, of itself, guarantee higher levels of security, since the feature still needs to be able to be used by the public and/or machines to verify banknotes and

difficult for a counterfeiter to mimic by some other means.

Finally, to maximise the effectiveness of the available space on a banknote, it was desirable to be able to integrate a number of the security features to further improve counterfeit resilience. In this way, more security features could be included so as to create secondary effects, thus creating a new, more complex element. An example is the combination of three security features – a window, optically variable ink (OVI) and a shadow image – which together create another ‘feature’ (Figure 1).

Figure 1: Integration of Security Features on the New \$5 Banknote



Source: RBA

Inevitably, any given feature involves trade-offs between the criteria so that the assessment process was not straightforward. Each of the potential security features identified by the Reserve Bank in its survey was ranked and short-listed on the basis of the factors listed above. The short-listed features were then tested for the ease of manufacturing in printing trials. This demonstrated that some of the prospective features presented significant production challenges and so were considered unsuitable. Other features were found to have durability issues, or did not integrate well with other security features or the overall design of the banknote, and were also discarded. From this process, a set of preferred features was identified and specified in an initial design brief. (Refer to 'Box A: New \$5 Banknote Security Features' for a listing of the security features incorporated into the new banknote.)

Design concept

Having selected the set of security features, the next step was to develop and refine the overall designs for the new banknote series. The Reserve Bank invited a number of designers to submit proposals. The designers, all of whom had previous experience designing banknotes, were provided with a brief that detailed the elements to be incorporated into the design concepts, including the general characteristics of the banknote, the narrative elements and the security features.

The brief required that the predominant colour, size and orientation of each denomination remain the same as the first polymer series. Similarly, based on long-term engagement with the vision-impaired community, the designs were required to retain the bold, contrasting numerals and size variations (Springer, Subramanian and Turton 2015). The brief also specified the inclusion and location of other elements, including portraits, serial number, signature block, denominational numerals and words, country name and a legal tender clause. Finally, the brief asked the designers to incorporate other narrative elements representative of the contributions to Australia of the various people portrayed as well as flora and fauna that are native to Australia.

The security features that were required on the design concepts included some features used on the first polymer series, as well as new features, including multiple clear windows, OVI elements, holographic devices and motion features. Where necessary, the brief specified the location of the features, their size and complexity and any required interactions with other features.

The designer that was judged to have best met the design brief and most effectively integrated the required features – emerystudio in Melbourne – was invited to submit a final set of design concepts for all of the denominations.

Banknotisation

While the final design concepts incorporated the general design layout, features and narratives for the new series, they were essentially artworks that needed to be adapted for banknote security printing and production. Note Printing Australia Limited (NPA), a wholly owned subsidiary of the Reserve Bank, is responsible for the practical design and production of Australia's banknotes. A 'banknotisation' brief was provided to guide the designers at NPA who had to convert the design concepts into actual banknote designs.

The banknotisation process is both complex and iterative. Each individual element and layer on the design concepts was drawn and optimised to account for production constraints. The integration of various features or layers – for example the use of optically variable ink on a clear window with a connected shadow image (Figure 1) – gave rise to further printing challenges that had to be taken into account when designing the integrated element. At times, elements that initially looked attractive and appeared to integrate well with each other and the overall concept design became less so after accounting for the printing variations inherent in a large-scale manufacturing process. In these cases, the designs were refined or narrative elements replaced – a process that was often repeated a number of times before the design was finalised.

Box A New \$5 Banknote Security Features

Key security features that the public can use to determine whether or not their banknote is genuine are shown and described in Figure A1 and

Table A1. There are also a number of features that are used by machines to authenticate banknotes, which are not listed below.

Figure A1: Security Features of the New \$5 Banknote



Source: RBA

Table A1: Security Features of the New \$5 Banknote

Polymer substrate	Australian banknotes are printed on polymer (a type of plastic) and have a distinctive feel. A genuine banknote should return back to shape after it is scrunched up.
Top-to-bottom window	There are multiple security features in the clear top-to-bottom window. The window should be an integral part of the banknote and not an addition.
3D Federation Star	Tilt the banknote to see a three-dimensional Federation Star with a colourful border. The image will appear raised or recessed.
Flying Eastern Spinebill	Tilt the banknote to see the Eastern Spinebill move its wings and change colour.
Colourful Eastern Spinebill	Tilt the banknote to see colours change within the Eastern Spinebill.
Reversing 5	Tilt the banknote to see the number '5' change direction within the Federation Pavilion. The number alternately appears forwards, disappears, then appears backwards.

Table A1: Security Features of the New \$5 Banknote (continued)

Rolling colour effect	Tilt the banknote to see a rolling colour effect. On one side of the banknote it is a prominent patch near the top corner; on the other it is in a bird shape.
Federation Star	Look for a Federation Star in a small clear window. The Federation Star is embossed and has a light and dark effect. The window should be an integral part of the banknote and not an addition.
Microprint	Look for tiny, clearly defined text in multiple locations on the banknote. This includes selected lines from the Australian Constitution in the branch in the top-to-bottom window, and in front of and in the wall of Parliament House. 'FIVE DOLLARS' is also microprinted in the coloured background.
Intaglio print	Feel the distinctive texture of the dark printing. The slightly raised print can be felt by running a finger across the portrait and numerals.
Background print	Multi-coloured and multi-directional fine-line patterns appear on each side of the banknote. This background printing should be very sharp. Check for irregularities such as less clearly defined patterns, thicker or thinner lines, or colour differences.
Fluorescent ink	Look for an Eastern Spinebill, serial number and year of print that fluoresce under UV light.

Source: RBA

Furthermore, banknote designs often look different when printed using banknote printing equipment compared with how they look on a computer screen. This is particularly true where different coloured inks interact with each other, and in areas where there is a reasonable amount of fine-line artwork. For this reason, multiple print trials were conducted at different phases to assess how the designs looked when printed. Following every print cycle, each printed element, as well as the design as a whole, was assessed in detail and feedback was provided to the banknote designers at NPA (Figure 2).

An additional part of the banknotisation process is the incorporation of features that are used by machines to process and authenticate banknotes. While the public cannot see these features, they need to be well designed to ensure that the banknotes can be used in the multitude

of machines that accept and dispense them. An important design consideration for these features is consistency across denominations in the series – the features should be the same and in similar positions on all the denominations. A common architecture was therefore developed that set out how the machine-readable features would be integrated across all the denominations. The Reserve Bank engaged with the banknote equipment manufacturing industry on the development of this architecture and it is now established as the roadmap by which the machine-readable features will be integrated across the series (Evans, Gallagher and Martz 2015).

Consultation

The Reserve Bank conducted extensive consultation on the banknote designs and this feedback was taken into account during the process of refining the design.

Figure 2: New Banknote Series Design Iterations



May 2011

This is a design concept from emerystudio incorporating the security features specified in the design brief.



August 2012

Following feedback that the image of Parliament House should appear more authoritative, an alternative reference image was incorporated.



April 2013

The large window, along with the OVI and several other elements, were developed further by the NPA designers.

Source: RBA



March 2014

One of the design iterations in which the large window design was being refined with the advice of acacia SMEs. The final OVI and hologram designs were incorporated.

The new series will showcase native Australian plants and birds as prominent themes, along with the existing portrait subjects from the first polymer series and their related images. A number of subject-matter experts (SMEs) were involved from an early stage to ensure that the representations were appropriate. SMEs were engaged to provide advice on ornithology, acacia and Australian history, particularly the areas and eras related to the portrait subjects.

The acacia and ornithology SMEs made recommendations on the species that could be featured. They provided information about the important characteristics of each species to the NPA banknote designers and reviewed the various design iterations. The challenge in this process was

to produce a representation that fitted into the limited space on the banknote, was printable and did not impede the efficacy of any security features. The most technically accurate representation, for example, might exceed the printing capability for a banknote. The aim of the SME consultation was, therefore, to produce a design that was an appropriate representation of the species while still meeting the requirements of the banknote printing process.

SMEs on the portrait subjects and Australian history were also involved from the start of the design process. They helped to source images and artworks that shaped the stories about the subjects of the portraits. These were usually images representative of a significant aspect of the portrait subject's life or

their contribution to Australian society. The process of selecting the images was also iterative: some images, for example, did not fit the available space and others could not be printed effectively.

The Reserve Bank also established a panel to assist in the assessment of the designs as they were developed. The Design Advisory Panel (DAP) comprises people with expertise in the areas of art, design, history and banknote production. The DAP typically meets twice a year to assess the banknote designs in terms of their historical accuracy and relevance, the appropriateness of images and themes, and any potential for elements to be misinterpreted by the public.

A number of focus groups were conducted with members of the public to give general feedback on the banknotes, as well as to evaluate the banknote designs for any adverse reactions by the public. Targeted focus groups were also conducted with people who are blind or have low vision to assist in the development of the tactile feature (Springer *et al* 2015); these groups helped to determine the preferred feature as well its design and location on the banknotes.

Production

The banknote production process involves the application of a sequence of printed layers that provide functionality, security and visual content. There are 13 production processes for the new \$5 banknote (see 'Box B: Production Process for the New Banknote Series' for a detailed listing of these processes). Some of these are extensions of existing production processes, sometimes updated with new materials, while others are entirely new and require new equipment.

One of the most significant changes was the incorporation of the clear top-to-bottom window. While internationally the design trend in polymer banknotes had been to use larger windows, a full-height window of the type included in the new banknote series had not been attempted before. This design presented a

number of challenges, both in production and for circulation. So prior to finalising the design, a preliminary set of trials was conducted to test the production readiness of the design and the ability of banknote equipment manufacturers to develop solutions to ensure their equipment could process the new banknotes. A test note was developed based on the general design proposed for the new series featuring a large clear window with multiple security features, a second window with an embossed feature and a third window that allows part of the rolling colour effect to be seen from the other side of the banknote. This test note went through the full production process in a variety of configurations to investigate optimum production conditions and the resulting notes were assessed for durability as well as compatibility with machine-based processing.

These trials demonstrated the suitability of several key features, allowing them to be confirmed for inclusion in the design. Two of these – the rolling colour effect and the multiple security features in the clear top-to-bottom window – required new production processes (see Foil and Screen Printing in 'Box B: Production Process for the New Banknote Series'). The success of the trial enabled NPA to introduce the new equipment into the banknote production process. In later trials, NPA, working closely with the Reserve Bank, was able to develop a process for the production of a tactile feature to assist people who are blind or have low vision to identify the value of their banknote (see Tactile Emboss in 'Box B: Production Process for the New Banknote Series').

Once all production considerations had been resolved, the design finalised and the trials successfully completed, full-scale production commenced. NPA began manufacturing the first denomination of the new series – the new \$5 – in 2016 and 172 million new banknotes were printed prior to their issuance on 1 September 2016. These banknotes have been made available to commercial banks to purchase at face value and issue to their customers as needed.

Box B

Production Process for the New Banknote Series

There are 13 production processes for the new banknotes. Some of these processes are also used in the production of the first polymer banknote series, while others are unique to the new banknotes.

Substrate Production

1. *Polymer.* Australian banknotes start as clear plastic beads, which are melted down and blown into a large bubble.
2. *Film production.* The walls of the bubble are pressed together and cooled to form laminated polymer film.
3. *Gravure.* Special inks are applied to make the film opaque, except for certain areas that are left free of ink to create the clear windows, before it is cut into sheets.

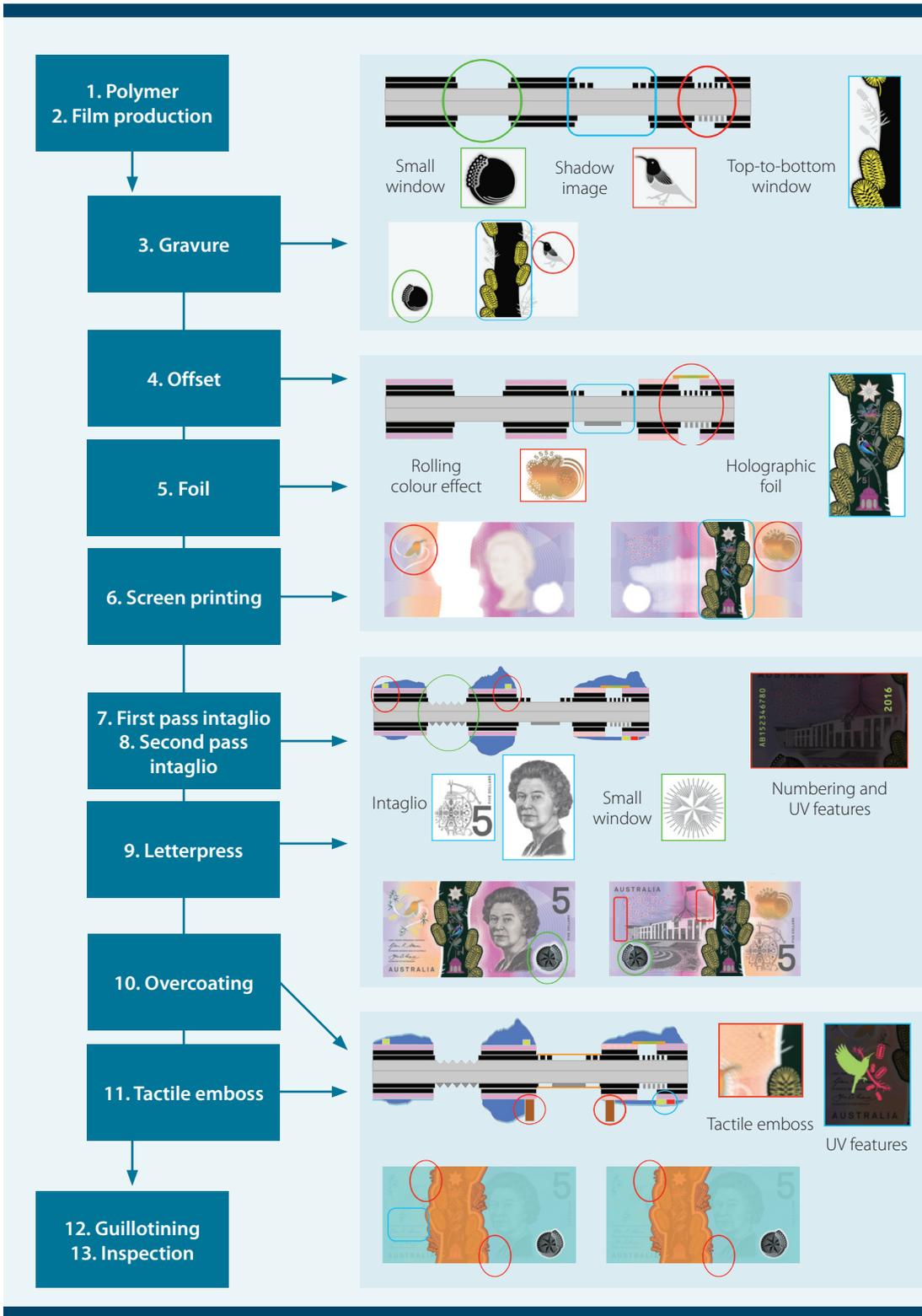
Printing

4. *Offset.* The background colours and patterns are printed onto both sides of the polymer sheets simultaneously on a 'simultan' printing machine. These machines can print up to 8 000 sheets per hour.
5. *Foil.* The multiple security features in the top-to-bottom window are applied as a continuous strip. This is the first unique process for the new banknotes.
6. *Screen printing.* The rolling colour effect is applied on a screen-printing process using an optically variable ink in a second unique process.
7. *First pass intaglio.* Major design elements, such as the portraits and narrative elements, are printed using intaglio printing machines. In this process, the ink is transferred to the sheets under great pressure using engraved metal plates.

8. *Second pass intaglio.* Separate print runs are required for each side of the sheet. The resulting raised print is one of the important security features of Australia's polymer banknotes. Some of the microprinting and embossed features are also produced during this process.
9. *Letterpress.* The serial number is added to the sheets using a letterpress printing process.
10. *Overcoating.* A protective overcoating ink is applied to the banknotes using a flexographic printing process. This overcoat contributes to the extended durability and cleanliness of polymer banknotes.
11. *Tactile emboss.* For the new series of banknotes, the tactile feature is applied in a final printing process. The tactile feature has been developed to assist the vision-impaired community to identify different denominations. It is made up of different numbers of raised bumps on the long edges of the banknote next to the clear top-to-bottom window.

Finishing

12. *Guillotining.* Printed sheets are guillotined into individual banknotes.
13. *Inspection.* Individual banknotes are inspected electronically to ensure that their quality meets the required standard. The finished banknotes are then shrink-wrapped, packed into containers and stored in a strong room prior to distribution around the country.



Conclusion

The process to develop a new banknote series from a design concept to finished banknote is extremely complex and iterative. This is particularly the case when the focus is on maximising the security benefits of the upgrade by ensuring that the most advanced technology is incorporated into the design in innovative ways. The time and effort required is an investment in the future security of Australia's banknotes thereby ensuring that the high level of confidence in Australia's banknotes is preserved.

Designs for the remaining denominations are well progressed and, over the coming years, the Reserve Bank and NPA will continue the banknotisation process until the full series is in circulation. ✎

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