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CASE REPORT

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The Use of an Electrostatic Detection Device to Identify Individual and Class Characteristics on Documents Produced by Printers and Copiers—A Preliminary Study*†

ABSTRACT: The market is inundated with inkjet printers, laser printers, and photocopiers, which are often used in criminal activities. Many of these office machines are built by various manufacturers, hence they are constructed with different hardware designs (e.g. "rolling" and "grabbing" mechanisms) that have changed over the years due to technological advances. Examinations of printed documents that involve the chemical analysis of ink colorants and the identification of physical machine defects such as trash marks are essential for the forensic examiner, but new techniques are needed to more closely identify a machine model or group of models. An electrostatic detection device (EDD) provides forensic examiners with a nondestructive method to examine indentations on a document. In this work, an EDD is used to detect latent physical markings left on documents by printers and photocopiers. Seventeen inkjet printers, 12 laser printers, and 3 photocopy machines were used to produce test documents. Physical markings were detectable in the large majority of the documents and were reproducible 100% of the time.

KEYWORDS: forensic science, questioned documents, printers, photocopiers, ESDA, EDD, inkjet, toner

The electrostatic detection device (EDD), first marketed by Foster and Freeman, Ltd., England, as the Electrostatic Detection Apparatus (ESDA), is an invaluable tool that provides forensic document examiners with a method to identify indentations on a document. Since ESDA is a nondestructive examination (with the exception of a brief humidifying process) that is highly sensitive and capable of creating a permanent record of results, it is commonly used in forensic laboratories. The use of ESDA is well documented in the literature and numerous articles have been published exploring parameters affecting quality and methods of enhancing results (1–6).

After conducting a literature search, no references were identified pertaining to the detection of latent physical impressions left on a document subsequent to being produced on a printer or copier. Moreover, there have been no discussions addressing directly the detection of unique latent markings on documents that may help to identify a particular machine. In the present study, the focus will be on printing devices and copiers that utilize inkjet or toner technology or both. These types of systems are widely available in the home and office, making them an opportune resource for criminal activity. Printers and copiers are also used in numerous types of transactions and can later become the focus of a criminal investigation. Accordingly, documents produced on these types of systems are often associated with a variety of crimes involving counterfeit identification documents, counterfeit financial obligations (e.g., currency and business checks), threatening letters, contracts, wills, financial accounts, and criminal record-keeping.

Linking two or more questioned documents (QD), associating a document(s) with a known office machine, determining the make and model of equipment, and/or authenticating a document with respect to date can be critical to a forensic investigation. The chemical analysis of inkjet ink and toner (7,8), as well as the identification of physical defects on documents, is an essential tool for the forensic examiner, but other applicable techniques to possibly identify a model or class of machines should be explored and validated. The market is inundated with printers and copiers since their popularity and usefulness continue to increase. There are numerous manufacturers and their hardware, or platform, designs (e.g., "rolling" and "grabbing" mechanisms) have changed over the years due to technological improvements. The printer platform, as defined for this study, will include all the hardware involved in transporting the paper through a printer from the pre-print (the paper is picked up and loaded into the print position) to the post-print (the paper is transported to a finished position). Indeed, changes in platforms that impart detectable and reproducible differences upon forensic examination may provide an examiner with information to make relevant and decisive conclusions.

Most inkjet and toner systems have three regions where the hardware components of the paper transporting mechanisms are likely to make physical contact with the paper. The first is when the paper

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† All references pertaining to manufacturers and their products do not imply endorsement by the United States Secret Service or the author.

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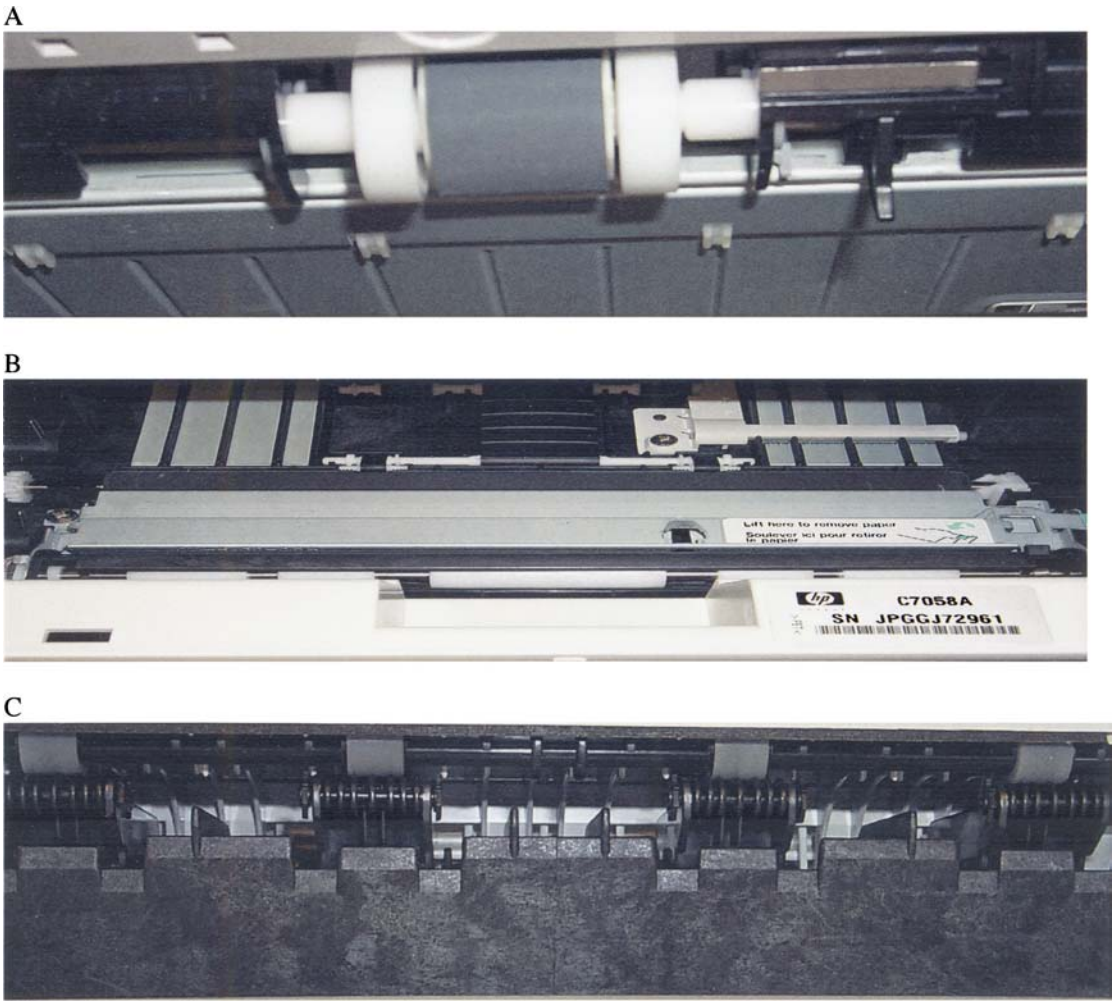

FIG. 1—*The three main areas a document may come in contact with the printer components of an HP LaserJet 2200d include:* (A) *paper intake area,* (B) *internal portion where printing takes place, and* (C) *paper output.*

is loaded and the intake begins. The second main area of contact will be during the printing process when the paper is gradually moved through the system. The final course in the paper path after the printing is complete is the paper output, where there is a mechanism to transport the paper out to its final rest position. Figure 1 shows the different areas where physical contact between the substrate and the printer hardware may take place.

At the outset of this study, the following five questions were proposed:

1. Do printers and/or copiers impart physical impressions on documents?
2. If physical impressions are present, are they detectable using ESDA?
3. Are the impressions reproducible?
4. Can the detectable impressions be used as class characteristics?
5. Can individual characteristics be determined using this methodology?

ESDA was used to examine documents produced from various printers and photocopiers. This information, e.g., class characteristics, could potentially be employed to determine the make and/or model of a machine. Furthermore, a forensic document examiner could use the information to verify the authenticity of a document with respect to date if information about hardware changes is obtained regarding the first date of availability of a particular hardware platform. Finally, this study will attempt to ascertain the feasibility of identifying individual characteristics that can be used to associate a questioned document(s) to a specific office machine.

Materials and Methods

Print samples were generated from 17 inkjet printers, 12 laser printers, and 3 photocopy machines. An inclusive list of the various office machine systems is included in Table 1. The documents were placed in a humidifying chamber for approximately 3–5 min. An ESDA examination was conducted on both sides of each page according to the Operating Instructions Manual provided by Foster and Freeman Ltd., England. This included running a known standard prior to employing ESDA on the test documents. Each page was reexamined a second time to later ascertain if resultant impressions were reproducible. An examination for impressions, striations, and fine minutiae was conducted.

Results and Discussion

The printers and copiers in this study operate on the premise of two technologies: inkjet and toner. The global market for inkjet

TABLE 1—*A list of inkjet printers, laser printers, and photocopy machines used to print documents that were subsequently examined using ESDA.*

Inkjet Printers	Laser Printers	Photocopy Machines
HP DeskJet 656C	HP LaserJet 4L	Kodak Image Source 50
HP DeskJet 855 C	HP LaserJet 5P	Xerox Document Center 425 DC
HP DeskJet 870 Cse (1)	HP LaserJet 6MP	Savin 2527
HP DeskJet 870 Cse (2)	HP LaserJet 1100	
HP DeskJet 870 Cse (3)	HP LaserJet 1200	
HP DeskJet 970 Cxi	HP LaserJet 2100	
HP DeskJet 970 Cxi	HP LaserJet 2200d (1)	
HP DeskJet 932C	HP LaserJet 2200d (2)	
HP DeskJet 5550	HP LaserJet 3100	
Canon BJC 6000	HP LaserJet 3200	
Canon Multipass C500	HP LaserJet 4000N	
Lexmark Z12	Lexmark Optra T610	
Epson Stylus Color 600		
Epson Stylus Color 740		
Epson Stylus Color 900		
Epson Stylus CX 5200		
Epson Stylus Photo 785 EPX		

systems is dominated by Canon, Epson, Hewlett Packard (HP), and Lexmark. Systems that use toner include laser printers and photocopiers. Some of the major producers of laser printers include HP and Lexmark, but companies such as Canon, Savin, Kodak, and Xerox are major manufacturers of photocopy machines. Therefore, various printers and copiers were examined from some of these companies to ascertain differences in the printer platforms. Figure 2 depicts representative samples of the different transport mechanisms used to feed paper into the print position in four different inkjet printers.

Printers and copiers have undergone significant changes since the early 1990s, resulting in unprecedented improvements. The quality of inkjet printing is defined and controlled by the printhead design, the ink, and the substrate, all of which have been refined resulting in superior printing quality. Frost and Dekalb (9) have addressed this issue with respect to the forensic examination of documents produced from inkjet systems. Also, toner-based systems have undergone changes to become more efficient and produce better quality products. To accommodate technological advances such as better print quality and faster printing, changes in the hardware designs might be expected. The introduction of additional or different hardware components then lends more significance to a conclusion since there is a more diverse population of office machines available. Consequently, forensic document examiners can use known historical changes in hardware to determine the earliest possible date a document was produced. This method, which requires an examiner to identify physical impressions and directly attribute them to a known printer, can be achieved in at least two ways. First, Buyers Laboratory, Inc. (Hackensack, NJ) publishes guides that provide comprehensive specifications of non-impact printers (10), digital copier-based multifunctional products (11), and more. The second method of compiling data can be accomplished by contacting manufacturers directly. Figure 3 shows some of the changes in the HP rollers found in the feed portion of inkjet printers. The printer platforms depicted in Figs. 2*A*, *B*, and *C*, were introduced into the market in 1990, 1995, and 1999, respectively.

Prior to performing an ESDA, a blank sheet of paper dusted with black magnetic powder was fed through an inkjet printer in an attempt to easily visualize the areas of mechanical contact. Numerous areas of physical contact were noted and are seen in Fig. 4. It was observed that impressions resulted from parts of the feeding mechanism (e.g., roller wheels and picker bars) on the front and back portions of the paper. Moreover, the markings on the front appeared to be positioned differently from those found on the back, indicating the importance of performing ESDA examinations on both sides of a questioned document.

After examining the documents printed from 17 inkjet printers, physical impressions directly attributable to some parts of the printer hardware were observed following ESDA in 13 of the documents. All the laser-printed and photocopied documents had markings that were discernible. Figure 5 shows an example of an ESDA examination performed on documents generated from four different inkjet printers, two laser printers, and two photocopiers. After reexamining the documents a second time to test for reproducibility, 100% had the same physical impressions. The presence of fine striations and minutiae is essential to the assessment. Thus, it cannot be emphasized enough that minimal and careful handling of documents is necessary since it is quite easy to impart artifact impressions that are detectable following an ESDA examination.

An important observation that was made in the photocopied specimens is the presence of horizontal striations (see Figs. 5*G* and 5*H*). This is likely the result of paper being loaded and fed in one position (e.g., vertical), then exiting in a perpendicular position (e.g., horizontal). Although it is routine to ascertain that a document was generated on a toner-based system, it is sometimes difficult for an examiner to determine if a QD was produced on a photocopier or laser printer. Identifying horizontal markings on a document may help resolve this question; however, further tests should be conducted on a larger sample size of photocopy and laser printer systems.

If allowed the opportunity, the physical examination of a questioned machine(s) components is crucial to understanding where resultant impressions are originating. There are numerous areas within a printer/copier that can physically touch the paper causing disturbances that are detectable by ESDA. It may not always be obvious what source in the printer is creating the detectable markings. Figure 6 demonstrates an example of identifying a particular component responsible for an indentation. It was necessary to physically examine the printer after the document was created to evaluate the ESDA results.

The need for familiarization with the hardware and an understanding of the components cannot be emphasized enough. As an example, three Epson Stylus Color printers (models 600, 740, and 900) are constructed on the same platform, but there are additional star wheels on the different models (see Fig. 7). After examining the paper exiting from the printer, the author noted that contact does not always occur between the paper and the star wheel. Physical contact is dependent on whether the tray is pulled out to catch the paper. The tray is designed to stop the paper from curling downward following the printing process.

Indeed, the identification of class characteristics on documents can be valuable information to corroborate and support additional investigative findings, but identifying individual characteristics is tremendously more substantive. Individual characteristics found on documents produced from a printing system will allow the forensic examiner to definitively link two or more questioned documents to each other and/or to a suspect office machine. Printers and copiers may incur significant repeating defects that are detectable during an ESDA examination. Artifact on or in the printer/copier such as pitting in the rollers, pieces of label, broken mechanisms, and/or correction fluids may cause individual markings in the resultant indentations. Also, a group of HP printers that are built on the same platform (e.g., wheel spacing at the paper intake) appeared

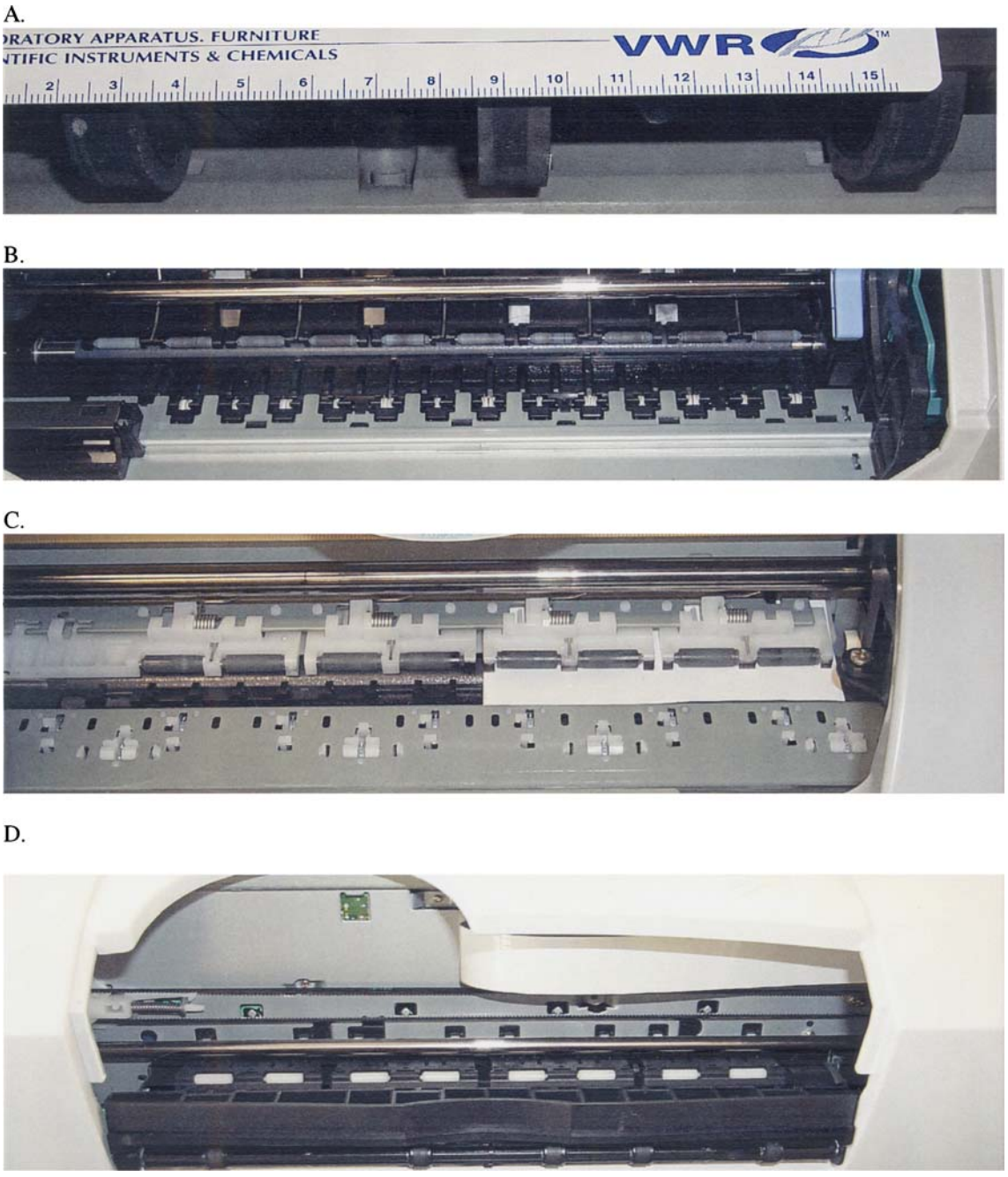

FIG. 2—*Some printer feeding mechanisms used by different manufacturers, including:* (A) *HP DeskJet 500,* (B) *Canon BJC-6000,* (C) *Epson Stylus Photo 785 EPX, and* (D) *Lexmark Z12.*

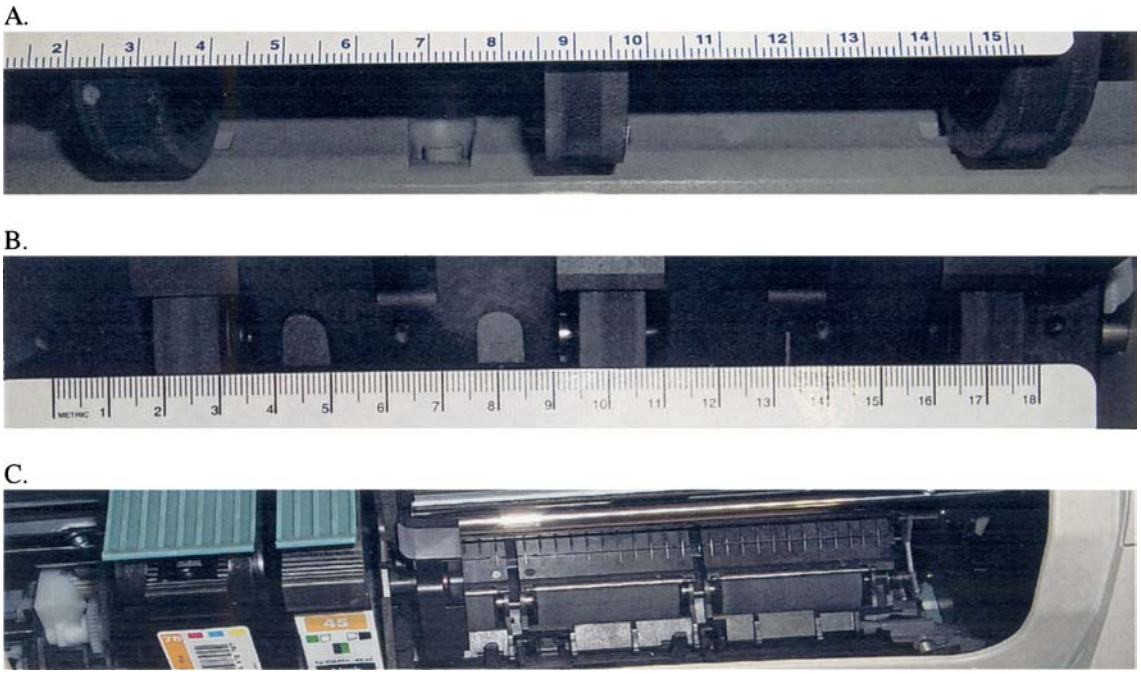

FIG. 3—*Evolution of hardware design and components within HP printers.* (A) *HP DeskJet 500 with wheels spaced at approximately 5.5 cm and 5.5 cm introduced into the market in 1990;* (B) *HP DeskJet 855C with wheels spaced at approximately 6.5 cm and 5.0 cm, which became first commercially available in 1995; and* (C) *HP DeskJet 970 Cxi with entirely new hardware components introduced in 1999.*

to impart slightly different physical markings. Figure 8 shows the different wear patterns on the wheels, which are likely the result of differential pressure at the point of contact as the paper is pulled into the printer. Figure 9 shows that the width of striations found on a document after an ESDA examination may be formed as a result of the differential pressure applied from wheels.

There are a number of procedural and interpretive cautions examiners should note. It is not unlikely that documents produced on the same printer will have some variation, depending on the handling of the documents, which may impart additional physical markings. If the results from two or more specimens are compared and there are differences, these may be explainable differences. Document examiners should consider alternate scenarios if there are different results when comparing specimens. For example, it is possible that documents that have gone through a mail facility will come in contact with rollers/wheels, or that a piece of paper without printing previously went through another printer or copier as an extra sheet. Resulting indentations that may or may not be detected on a document could be the result of paper differences (e.g., thickness and coating), the "wear and tear" of the system, the mode of printing (e.g., landscape, portrait, bold font), and/or batch differences in the manufacturing of the hardware such as pressure points between a wheel and the document. One possible serendipitous discovery that may benefit document examiners in the future can be observed in Fig. 4*A*. Following the ESDA examination, a crisscross pattern was observed on the document. Further tests on blank pieces of paper indicated that this configuration was the result of the papermaking process. Indeed, an examiner needs to remain aware that the production of paper may create patterns evidenced by ESDA. This may be beneficial when conducting paper examinations such as the comparison of multiple documents or an assessment of the manufacturing origin of the paper(s). Finally, one also needs to remain cognizant of original equipment manufacturers producing printers and copiers. These machines are typically built with the same hardware and use the same ink/toner, but are marketed under a different brand name (e.g., HP and Appolo or Lexmark and Compaq). Finally, if feasible, it is highly recommended that the examiner obtain multiple specimens from a known office machine to ensure reproducibility and possibly explain differences.

Conclusion

With the rise in the use of office machine systems utilizing inkjet and toner technology to commit criminal acts, linking questioned documents and/or suspect machines can be vital to a forensic investigation. The findings in this study have been very promising based on observations and theory. Indeed, it has been shown that printers and copiers can impart reproducible physical impressions on paper which are detectable using ESDA. Performing chemical examinations on inks and toners still remains an invaluable technique for comparing questioned documents and is widely used to determine the make and model of a suspect machine(s) when compared to standard reference material. Nonetheless, physical examinations for striations and fine minutiae found on a document(s) can corroborate ink findings, as well as possibly narrow the field of possible machines. The future of printer and copier analyses may likely involve other physical and chemical examinations. Image analysis software, which is often implemented by manufacturers to conduct quality assurance procedures, is used to study the physical properties of documents produced on copiers and printers. Ultimately, their use may be realized in forensic laboratories. Also, more sophisticated examinations of ink chemistry such as elemental analysis using laser ablation inductively coupled plasma/mass spectrometry (ICP/MS) may provide examiners with further detail. Preliminary studies at the United States Secret Service have indicated that the elemental profiles of inkjet inks can be discriminating. The results from this research have provided a foundation to better evaluate the feasibility of developing a database of standard reference material. Creating an arsenal of examination techniques, including physical

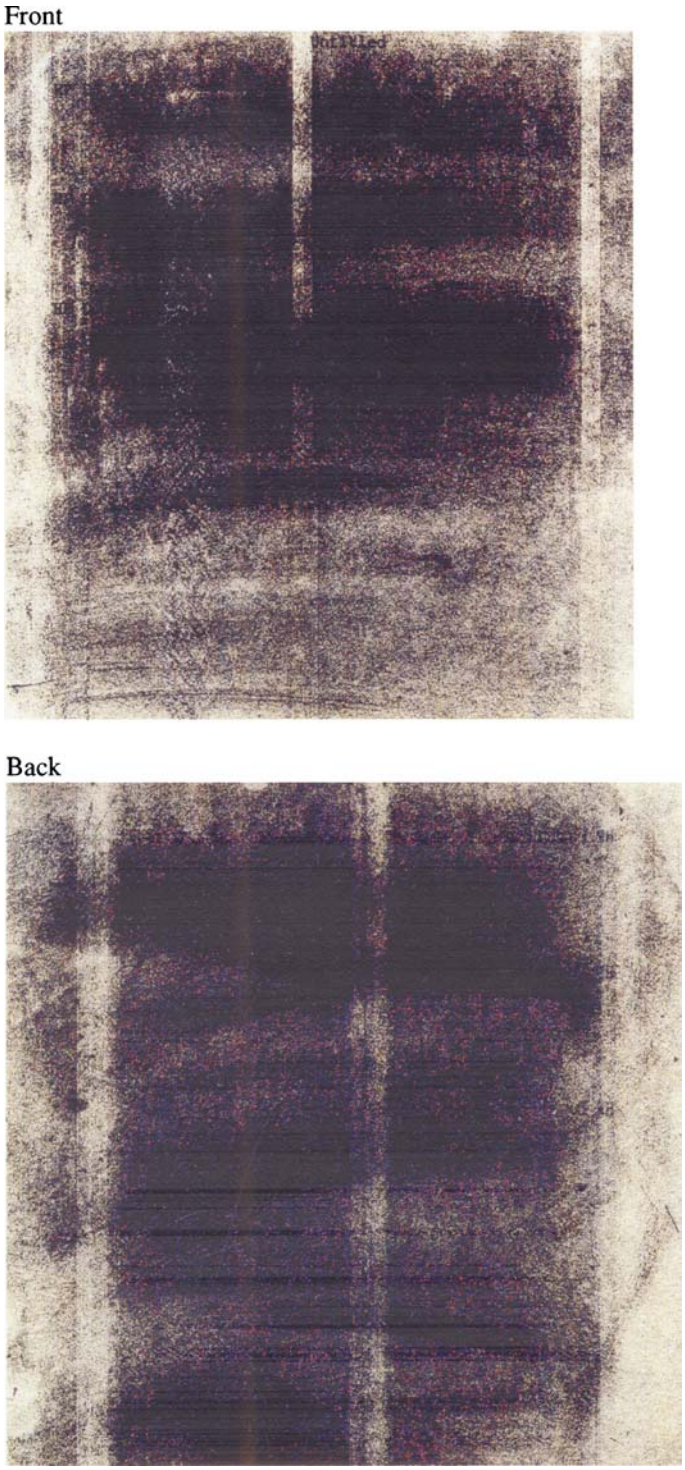

FIG. 4—*A piece of blank paper covered with black fingerprint powder and passed through a HP Deskjet 870 Cse printer to show some of the areas where physical contact between substrate and hardware components was made.*

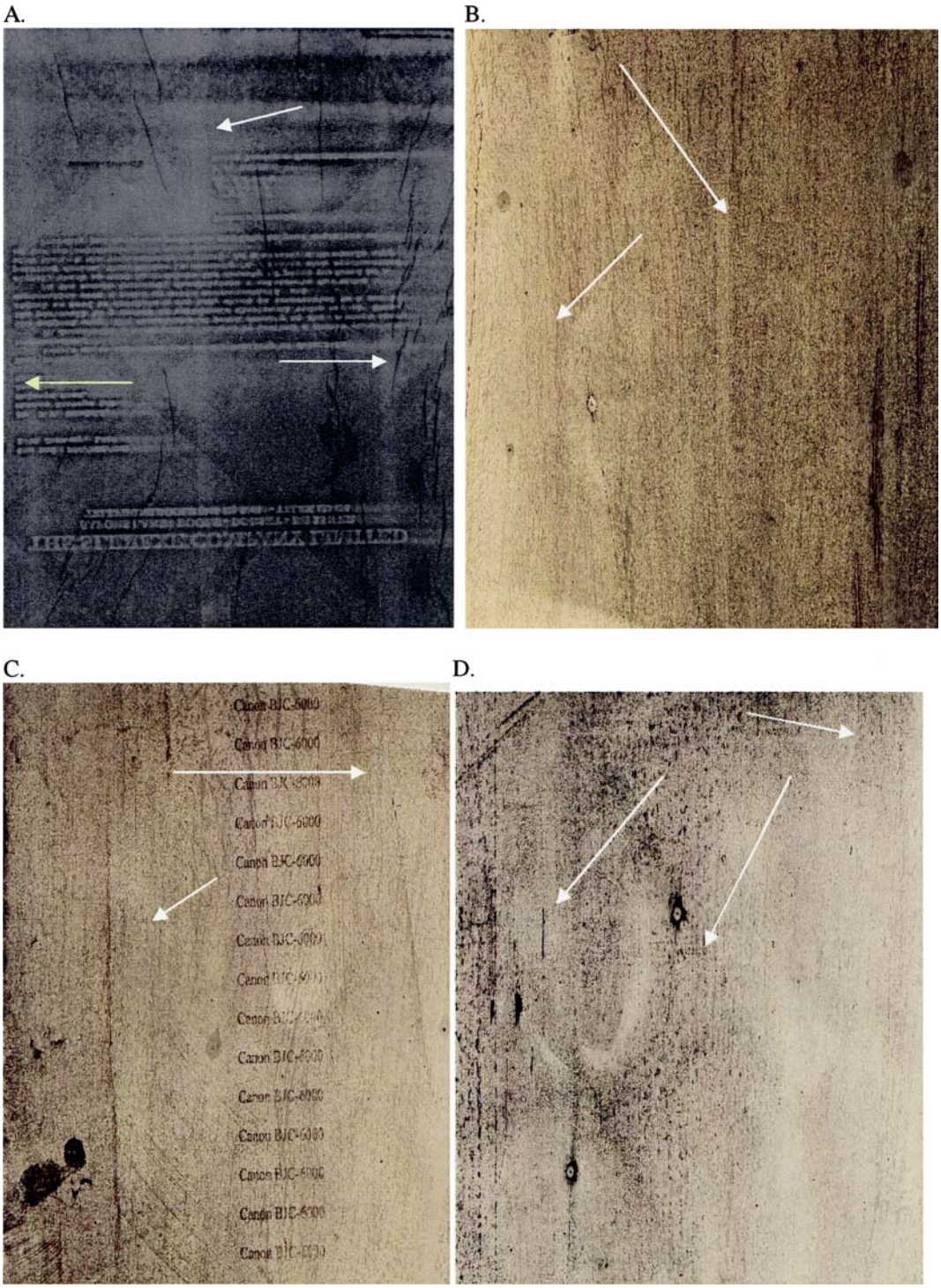

FIG. 5—*Areas of indentation from ESDA impressions attributable to some of the paper feeding mechanisms found in:* (A) *HP 656 C,* (B) *HP 870 Cse,* (C) *Canon BJC 6000,* (D) *Lexmark Z12,* (E) *HP LaserJet 3100,* (F) *HP LaserJet 4L,* (G) *Xerox Docucenter, Photocopier, and* (H) *Kodak ImageSource.*

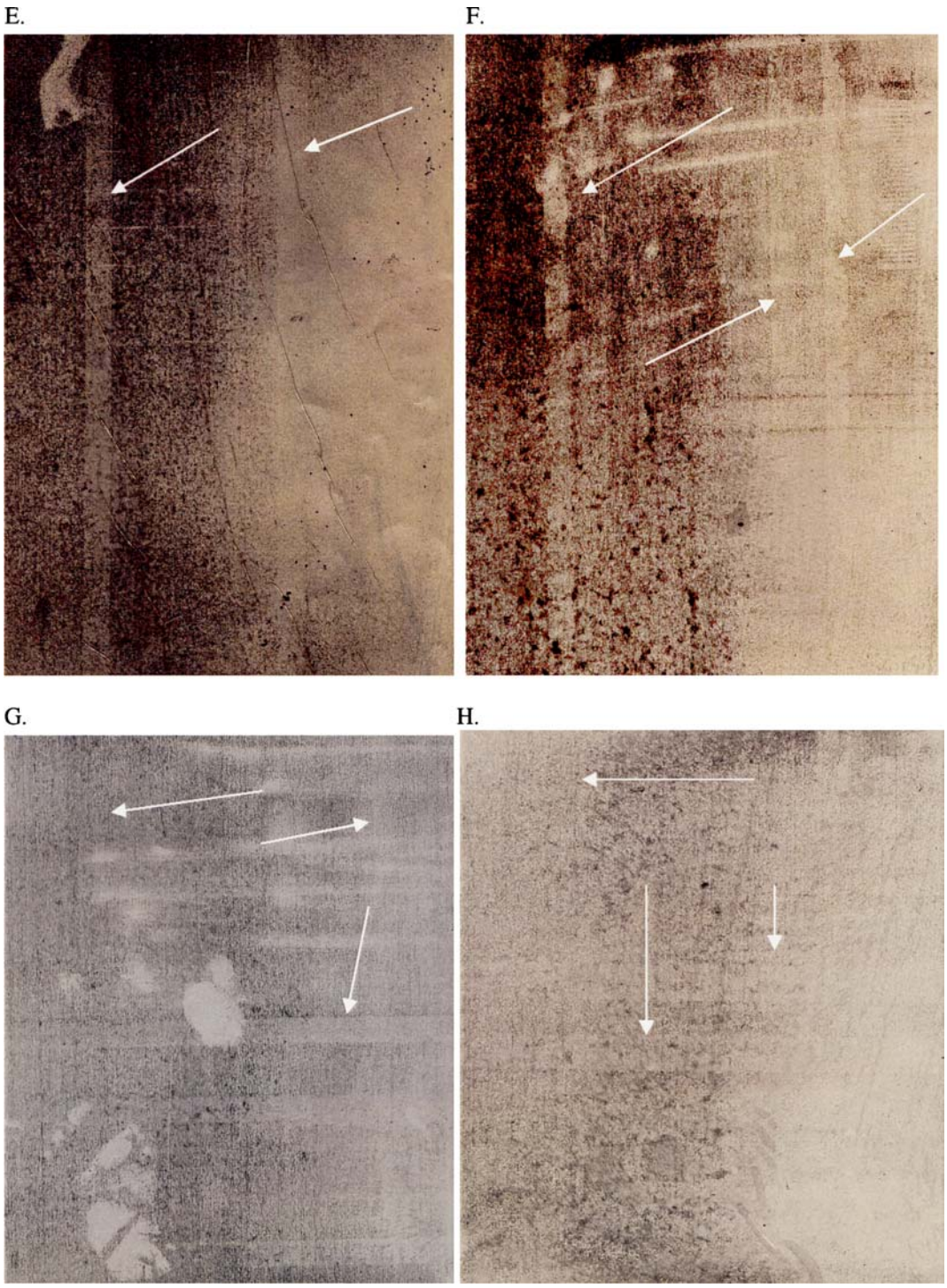

FIG. 5—*Continued.*

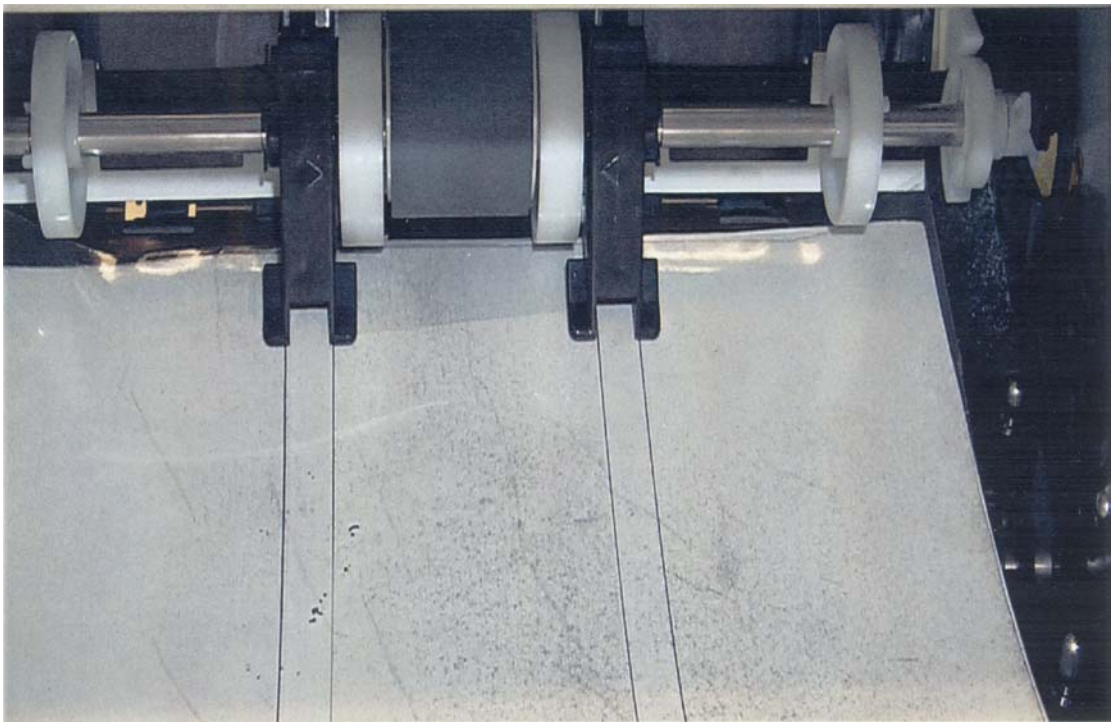

FIG. 6—*A demonstration and reconstruction of the striations made on a document produced on a HP LaserJet 3100. The peripheral areas of the vertical striations were outlined for demonstration.*

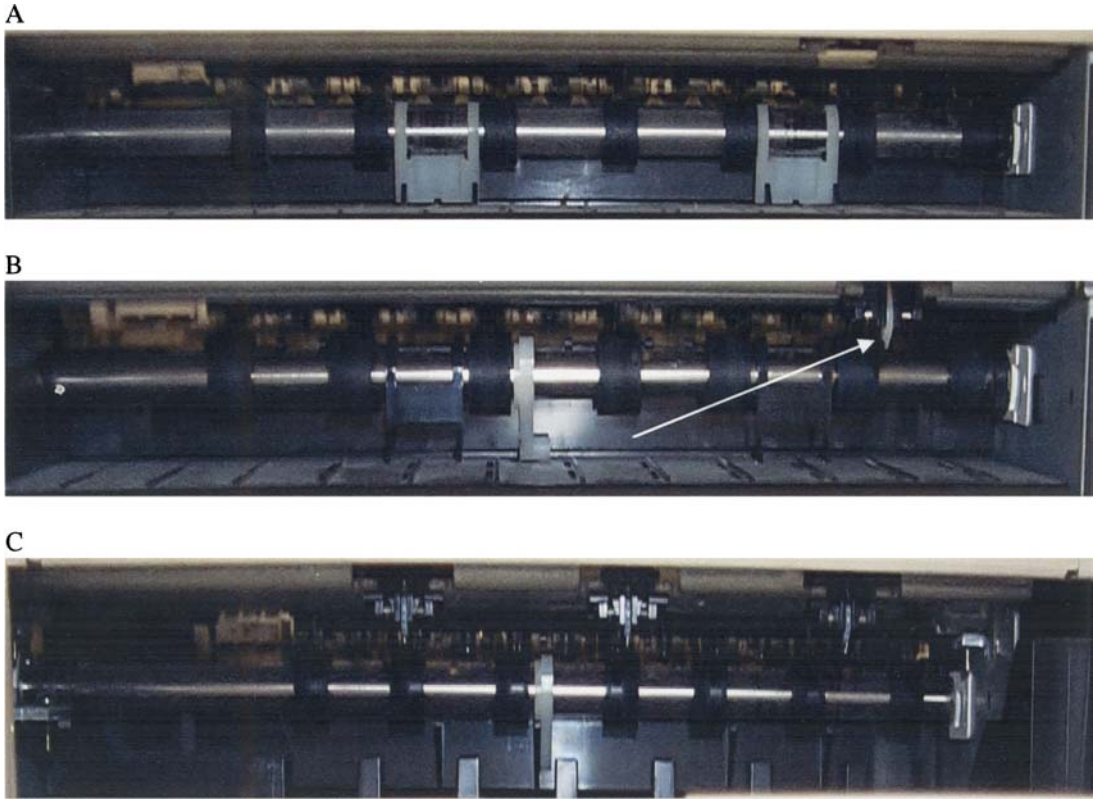

FIG. 7—*An example of the presence or absence of star wheels present on three models of Epson Stylus Color printers, model numbers:* (A) *600 (star wheel absent),* (B) *740 (one star wheel found in the right portion), and* (C) *900 (three star wheels).*

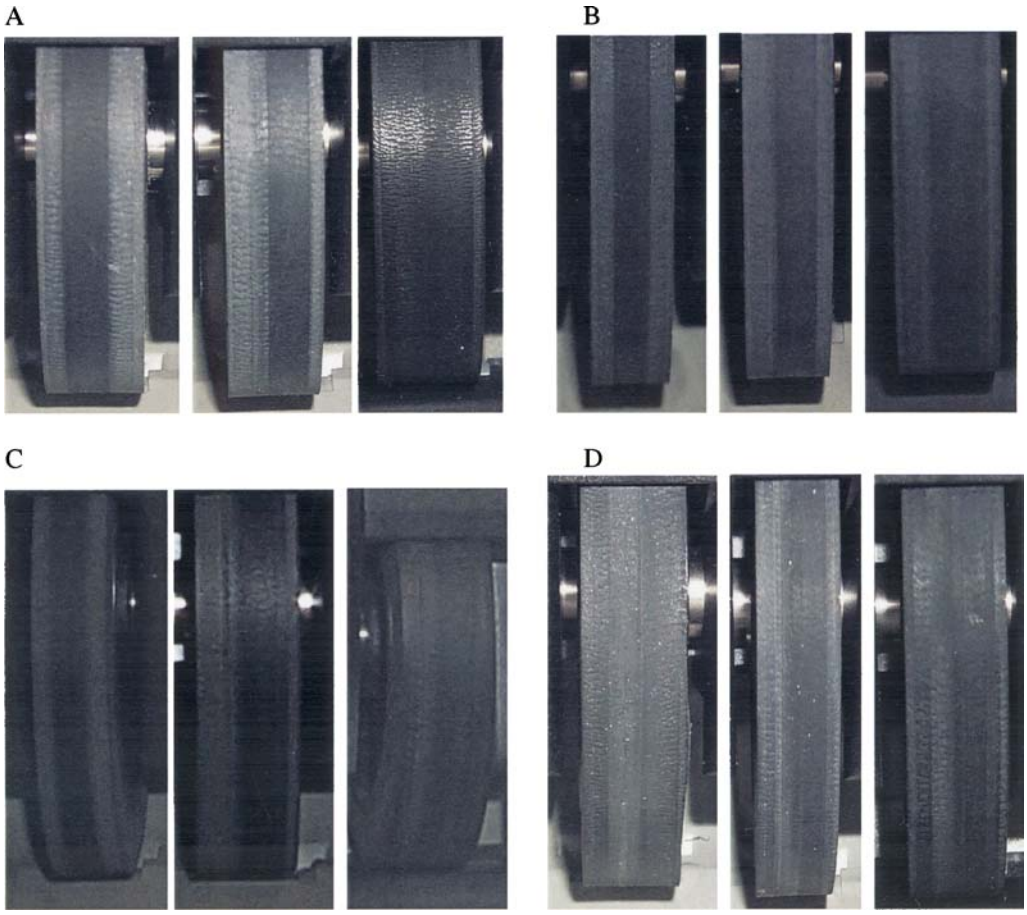

FIG. 8—*Four different HP printers with the same wheel spacing but different wear patterns on each series of wheels:* (A) *HP DeskJet 870 Cse,* (B) *HP DeskJet 870 Cse,* (C) *HP DeskJet 870 Cse, and* (D) *HP DeskJet 855 C.*

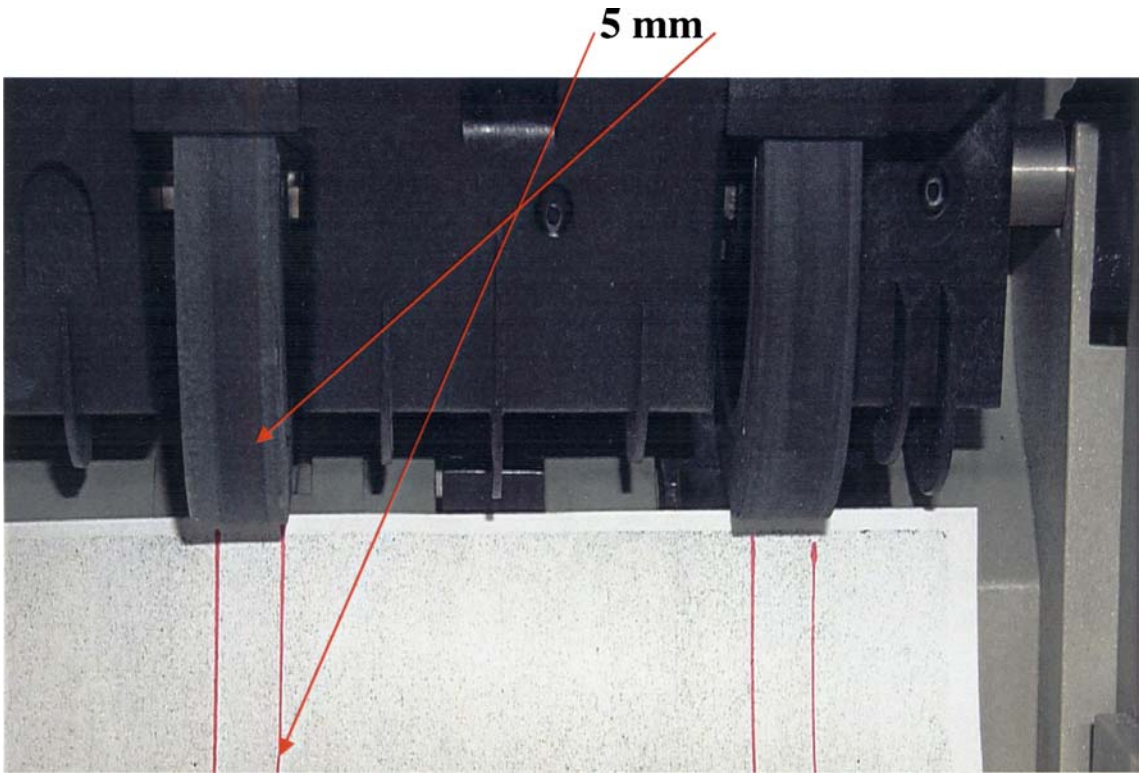

FIG. 9—*Width of striations formed may be the result of differential pressure applied where wheels come in contact with paper. The width of the wear pattern and striations is 5 mm.*

and chemical analyses, will allow document examiners to better evaluate questioned documents produced on printers and copiers.

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