

Determining the Sequence of Original Ink Writing and Toner Printing

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Document examiners are frequently called upon to determine the sequence in which intersecting entries were written. This paper arises from research undertaken to determine the sequence of intersecting original ink writings and toner-printed text. One might intuitively expect that writing over toner would not penetrate the toner. Tests were undertaken based on documents produced on a Hewlett Packard LaserJet printer and a combination of 70 different writing instruments. The subject intersections were prepared to test both sequences of ink *before* toner and ink *after* toner. The points of intersection were examined microscopically before and after the removal of the toner. Corresponding intersections for the 2 sequences were compared. It was found that the extent to which the ink penetrated the toner varied between different ink types.

Introduction

This research stems from case work involving a disputed will. The will comprised 6 pages, each bearing poor quality toner-printed text, an original blue fluid-ink testator signature, and 2 witness signatures. The testator signatures exhibited a reasonably complex structure. They were executed fluently and without any noticeable writing pressure. Numerous similarities and no significant differences were found between each of the testator signatures and the specimen signatures forwarded for examination. There was no evidence of free-hand simulation or tracing. It was concluded that each of the testator signatures was genuine. A number of techniques have been developed over the years to determine the sequence of writing by the examination of intersecting strokes (Radley, 1993; Poulin, 1996; Planty, 1997; Liu, Cheng, Shieh, Miou, and Jeng, 1997). This paper supports the premise that caution should be exercised in making a determination of the sequence or strokes relating to original ink writing and toner printing.

On pages 4 and 6 of the will, the testator signatures intersected with the toner-printed text. Microscopic examination of these points of intersection did not reveal any depression of the toner line or spectral reflectance which would establish that one or both signatures were written *after* the printing of the text. Furthermore, the lack of any pressure in the ink lines of the signatures

precluded any determination as to the significance of the absence of a depression of the toner line, which might establish that the signature was written *before* the printing of the text. Therefore, it was necessary to remove the toner at a number of these points of intersection to possibly determine the order of placement of the signature and of the printed text on the 2 pages. As destructive testing was involved, permission was obtained from the parties involved.

One might intuitively expect that if the signature was written *before* printing the text there would be ink present under the toner line, and that if the signature was written *after* printing the text there would not. Toner was carefully removed using a sharp blade at 3 points of intersection between each of the 2 signatures and the text. At each of these 3 points the ink lines appeared uninterrupted, both in apparent concentration of ink and width of the ink line. These observations supported the proposition that, at least on pages 4 and 6 of the will, the testator signatures had been written *before* printing the text. That is to say, the observations appeared to be supportive of a proposition that at least these 2 testator signatures had been written on blank sheets of paper. The only other possible explanation was that at each intersection the ink had penetrated the toner line and absorbed into the paper fibers so completely and so exactly that the result was an apparent continuous ink line beneath

Brand/Model of Fluid Ink Pen	Color/s
Artline 200 Fine 0.4 (fiber tip)	blue, black, red, pink, purple, green, brown, orange
Schwan Stabilo Point (fiber tip)	blue, black, green
Pilot Rollerball	blue, black, red
Pilot Explorer (rollerball)	red
Ball Pentel (rollerball)	black, red
Pentel Superball (rollerball)	blue
Uni-ball Eye (rollerball)	blue, red
Uni-ball Micro (rollerball)	black
Uni-ball Zirco (rollerball)	red
Artline 210 (marker pen)	black
Artline Calligraphy (marker pen)	silver
Artline 700 (marker pen)	blue, black, red, green
Pentel Maxiflow Permanent Marker	blue, black, red, green
Stabilo Boss (highlighter)	blue, mauve, pink, orange, yellow, green, turquoise, purple

Table 1a. List of fluid ink pens tested in this study.

Brand/Model of Gel Pen	Color/s
Pentel Hybrid Rollers	blue, purple, green, pink, orange
Pentel	purple
PaperMate Gel Stick	purple
Jimnie Gel	blue, pink

Table 1b. List of gel pens tested in this study.

Brand/Model of Ballpoint Pen	Color/s
BIC	blue, black
PaperMate	blue
PaperMate Flexgrip	blue, black
PaperMate Replay	blue, black
PaperMate Kilometric	blue
Staedtler	purple
Staedtler Stick	blue, red
Pilot BP-S	black
Faber Castell	blue
Faber Fix	blue, black, red
Penline	purple
Luxor Ranger	blue
Artic	blue, black
Wilson Sly 400	red

Table 1c. List of ballpoint pens tested in this study.

the toner. Given such surprising circumstances, tests were conducted on a number of intersections of ink and toner where the ink lines were created both *before* and *after* the toner printing.

Methods and Materials

Test sheets of 9 rows of 28 bold vertical bars (with a 60-point font size) were printed on a Hewlett Packard LaserJet 4050N printer (Figure 1).

A range of 70 fiber-tip, rollerball, permanent markers, highlighters, gel ink, and ballpoint pens were tested (Tables 1a, 1b, 1c). Three horizontal ruled lines of ink were drawn with reasonable fluency using each pen to create intersections between the ink and toner. Tests were prepared for the investigation of both sequences—ink *before* toner and ink *after* toner. After preparing the ink lines for the sequence of ink *before* toner, a period of at least 24 hours lapsed before printing

the toner lines. A similar time period was allowed to lapse after the printing of the toner lines for the sequence of ink *after* toner.

All intersections were examined by means of toner removal regardless of when the order of the ink and toner was obvious by spectral reflectance or depression of the toner lines. Preliminary observations of spectral reflectance (or absence thereof) were noted for all intersections with the sequence of ink *after* toner. The depression or otherwise of the toner lines, however, was not recorded, as this can be an effect of a combination of pen pressure, writing instrument, and writing surface.

So as not to disturb the paper fibers, toner was removed by scraping with the flat edge of a sharp blade along the toner line at each point of intersection. Sections of the ink lines without toner were subjected to similar scraping with the blade to ensure that this action did not disturb

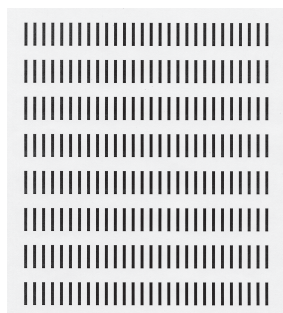


Figure 1. Example of test sheet of rows of 28 bold vertical bars at 60 point font size printed using a Hewlett Packard LaserJet 4050N printer.

the ink saturated fibers and thus interfere with the appearance of the ink line. The exposed portions of the ink line were examined microscopically to observe the apparent concentration of ink and ink line width at the point of intersection with the toner. The appearance of the ink at the point of intersection with the toner was then compared to the appearance of the remainder of that ink line. Corresponding intersections for the 2 sequences were also compared. At least 9 intersections were examined for each ink on tests for the sequence of ink *before* toner. With the exception of intersections with ballpoint pen ink, at least 18 intersections were examined for each ink on tests for the sequence of ink *after* toner. Nine intersections for each ballpoint pen ink were examined on tests for the sequence of ink *after* toner.

The appearances of the ink lines were noted for each group of intersections for each ink. The appearances of the ink lines on tests for the sequence of ink *after* toner were subjectively classified as follows:

- “C” Complete penetration of the toner by the ink—ink concentration and ink line width indistinguishable from the remainder of the ink line,
- “P” Partial/incomplete penetration of the toner by the ink—white paper fibers still visible and/or ink line width narrower compared to the remainder of the ink line, and
- “N” No penetration of the toner by the ink—complete interruption of the ink line.

Results

Ink Before Toner

As expected, and with only 2 exceptions, the apparent concentration of ink and ink line width was consistent through the points of intersection with the toner printing for the sequence of ink *before* toner. The exceptions were the blue and black PaperMate Replay ballpoint pen inks which, when the ink lines were created before the toner, were removed when the toner was removed (Figure 2). These pens contain “erasable” ink and come equipped with erasers. The relative ease with which the toner could be removed from the ink line was noted compared with toner removal directly from the paper where there was no ink.

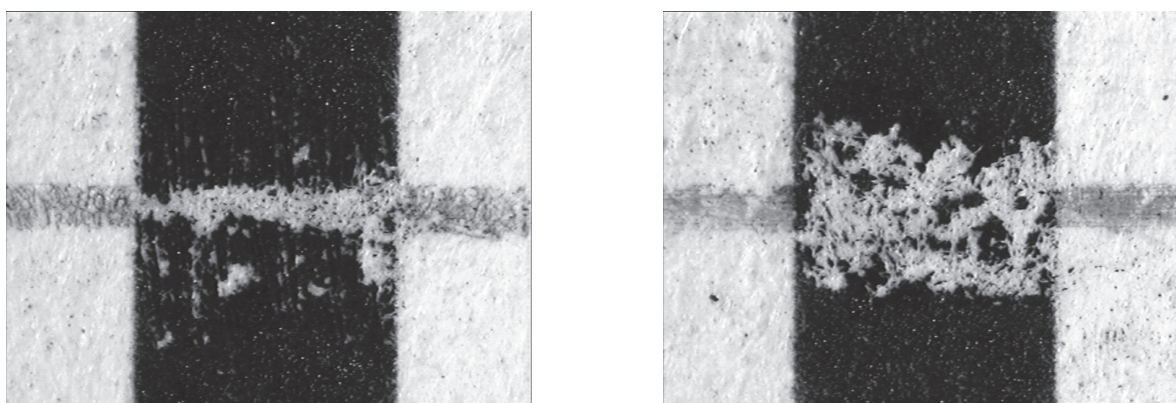


Figure 2. Microscopic images of PaperMate Replay blue ballpoint pen inks lines and toner demonstrating ink *before* toner (left image) and ink *after* toner (right image).

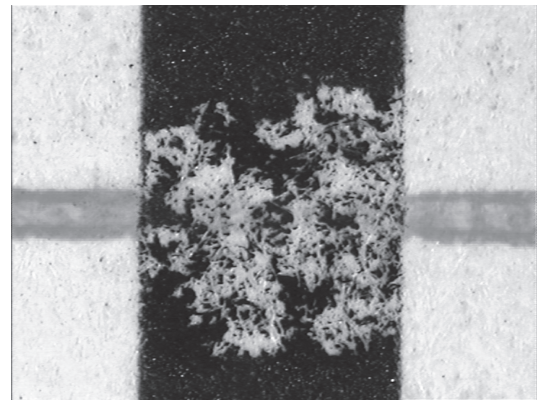
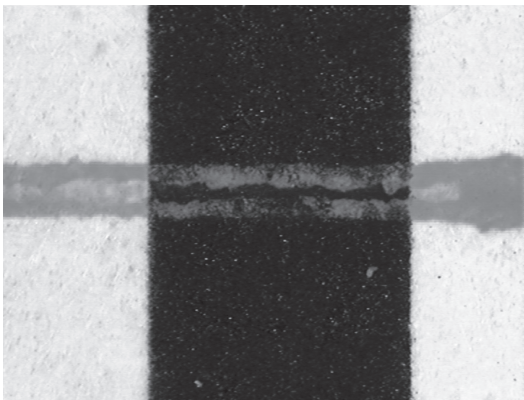
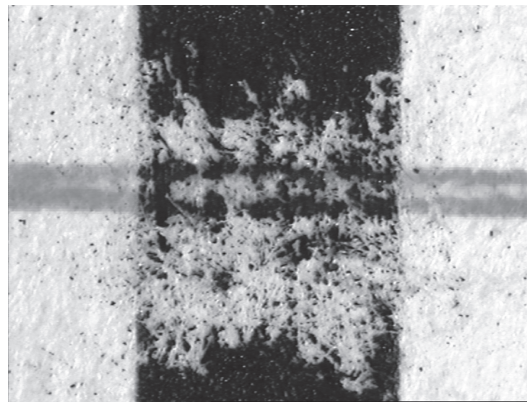


Figure 3. Microscopic images of ink lines from the Pentel Hybrid red roller intersecting with toner demonstrating ink *before* toner (upper image) and ink *after* toner (lower left image *before* the toner was removed and lower right image *after* the toner was removed).

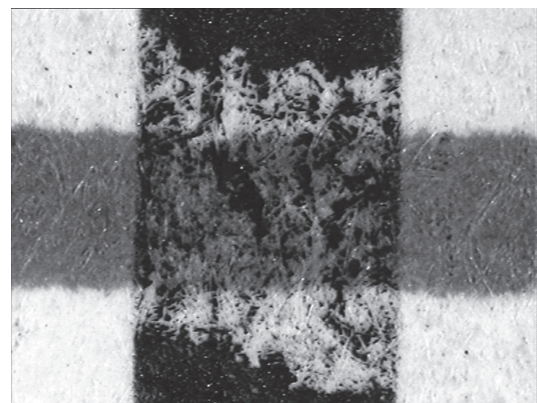
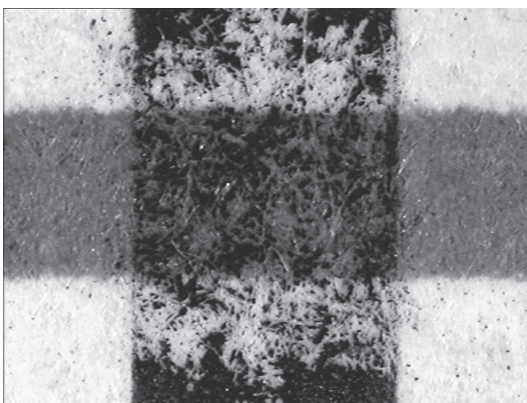


Figure 4. Microscopic images of the ink lines from Pentel Maxiflo blue permanent marker pen intersecting with toner ink *before* toner (left image) and ink *after* toner (right image).

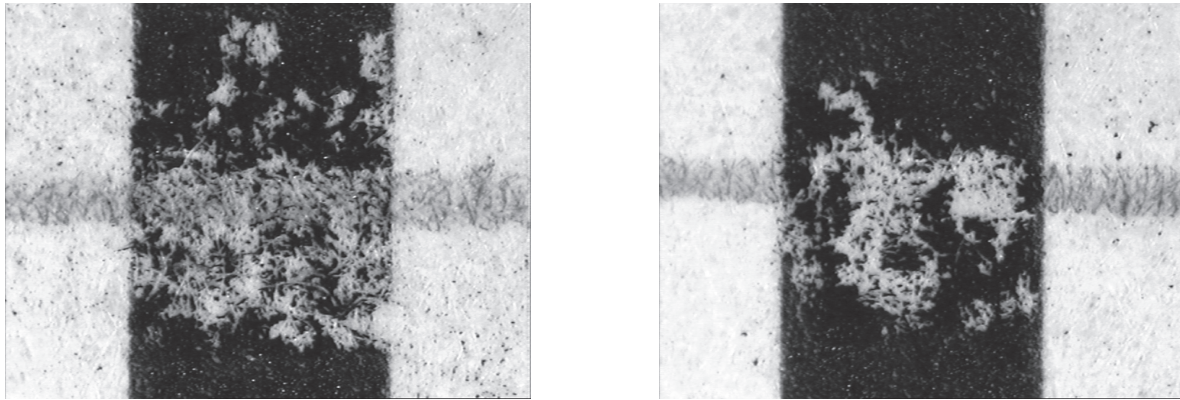


Figure 5. Microscopic images of ink from the Faber Fix blue ballpoint pen intersecting with toner demonstrating ink *before* toner (left image) and ink *after* toner (right image).

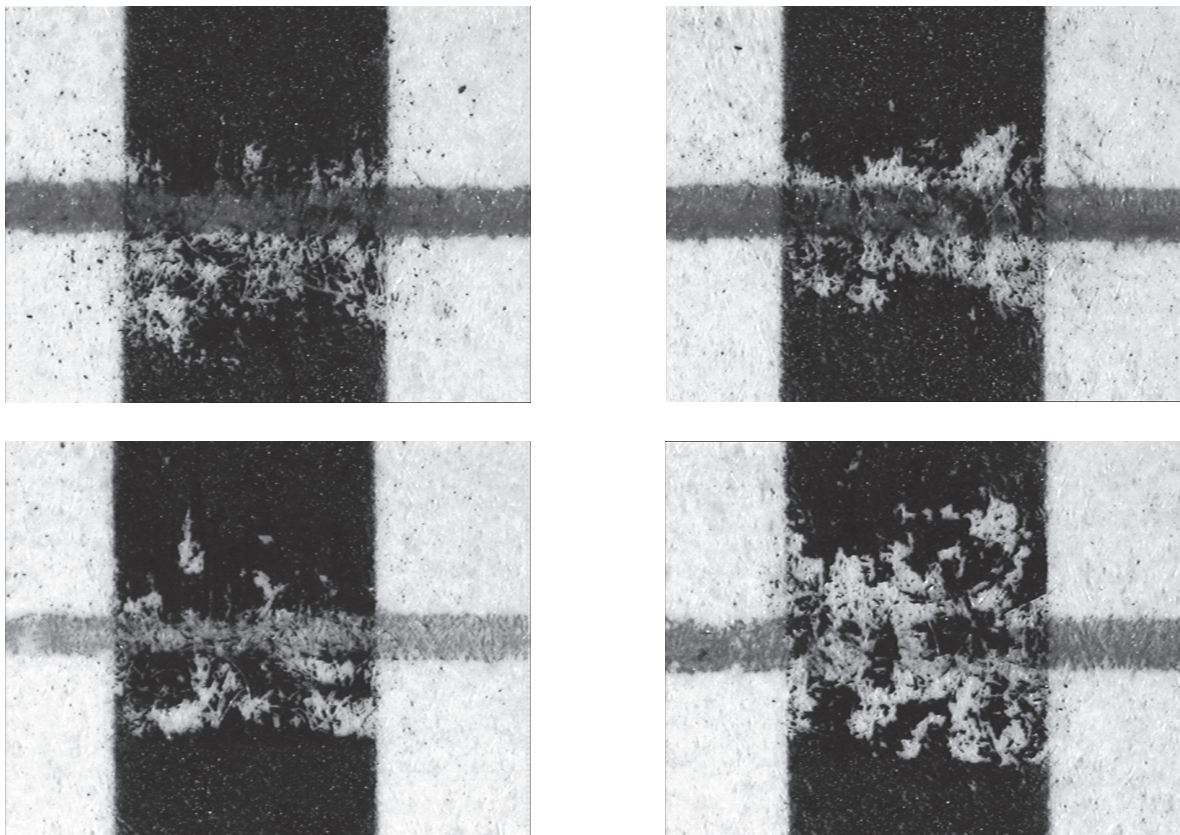


Figure 6. Microscopic images of ink lines from the Pilot Explorer red rollerball pen (upper images) and the Faber Fix red ballpoint pen (lower images) intersecting with toner and demonstrating ink *before* toner (left images) and ink *after* toner (right images).

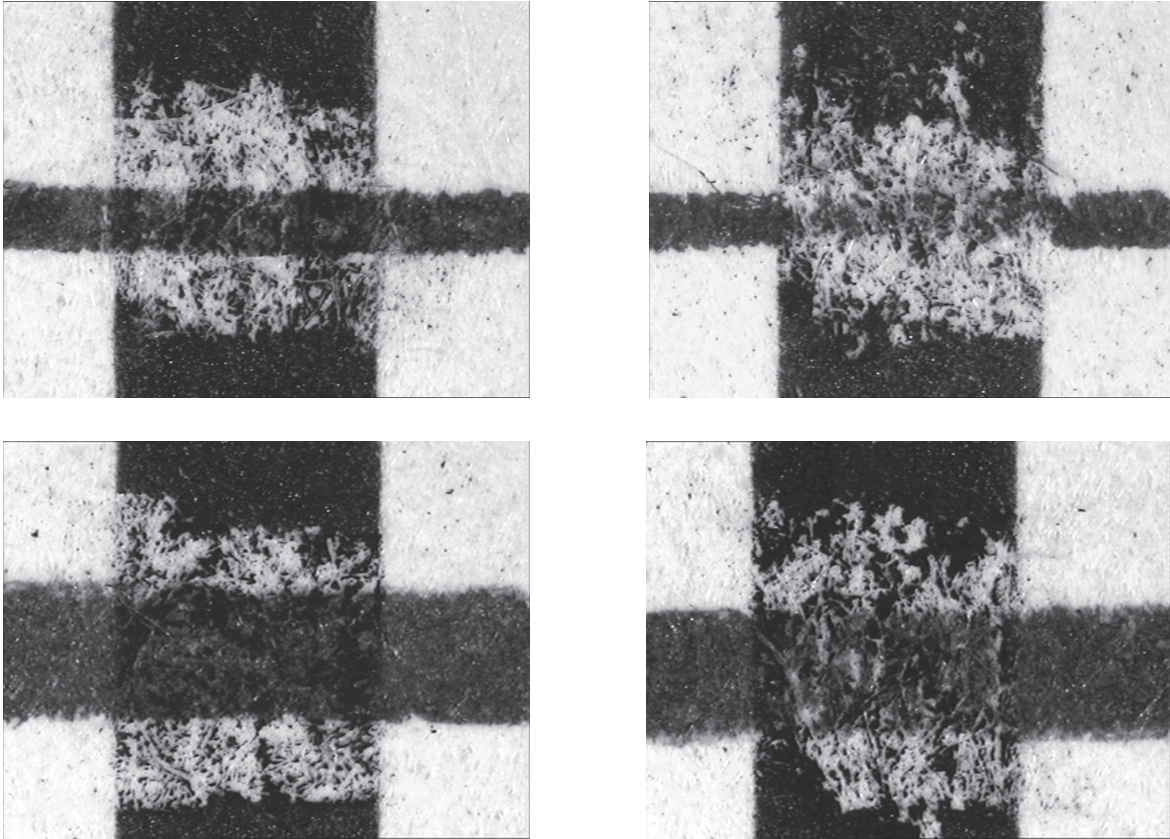


Figure 7. Microscopic images of ink lines from the Ball Pentel black rollerball pen (upper images) and the Artline 700 black marker pen (lower images) intersecting with toner: ink *before* toner (left images) and ink *after* toner (right images).

Additional findings noted using other pen inks *before* toner were:

- a. Fluid inks from rollerball and fiber-tip pens varied from no noticeable difference between removing toner from the ink line than from the paper, to the toner being easier to remove from the ink line than from the paper.
- b. Fluid inks from marker pens (except the Artline 210) and highlighters were found to have no noticeable difference between removing toner from the ink line and removing the toner from the paper.
- c. Artline 210 marker pen created a situation whereby the toner was markedly more difficult to remove from the ink line than from the paper.
- d. Artline Calligraphy pen had very poor toner adhesion to the ink line during the printing process.
- e. Hybrid rollers and gel pens (except blue Jimmie Gel pen) produced an intermittent and unevenly inked "railway track" like ink line (Figure 3). Some of the ink in the areas where there is a thicker deposit (on the ink line edges or goops) may be removed when the toner is removed. However, particularly along the edges of the ink line, the toner is more difficult to remove from the ink line than from the paper.
- f. Blue Jimmie Gel pen was found to have a similar appearance to fiber-tip fluid ink lines and easier to remove toner from the ink line than from the paper.
- g. Ballpoint pen usage was found to have easier removal of toner from the ink line than from the paper.

Ink After Toner

Table 2 lists the observations in accordance with the classifications "C," "P," and "N" described

above for the appearance of the ink line at intersections for the sequence of ink *after* toner.

Discussion

On the basis of these observations, the following general comments can be made with respect to the sequence of ink *after* toner.

- (i) Of the different writing instruments, the inks from the marker pens were found to penetrate the toner to the greatest extent (Figure 4). In most instances there was complete penetration of the toner by the ink such that the apparent ink concentration and ink line width at the points of intersection with the toner were indistinguishable from the remainder of the ink line and from the ink line at intersections for the sequence of ink *before* toner.
- (ii) Of the different writing instruments, the inks from the ballpoint pens were found to penetrate the toner the least (Figure 5). In most instances there was no penetration of the toner by the ink such that there was a complete interruption of the ink line at the point of intersection with the toner.
- (iii) Red, purple, and pink inks were found to penetrate the toner the most, including ballpoint pen inks (Figure 6).
- (iv) Of the different color inks, black inks were found to penetrate the toner the least, including marker pen inks (Figure 7).

Conclusions

It is evident that many different inks of varying colors can and do penetrate toner printing. It cannot, therefore, be assumed that the presence of ink underneath toner necessarily establishes that the ink line was drawn before the toner line was printed. However, qualified conclusions can be expressed in many cases when the ink type and apparent concentration and width of the ink line are taken into account.

In the particular case that gave the impetus for this research, the observations were more supportive of a proposition that the signatures on at least pages 4 and 6 of the will were written *before* the text was printed than of a proposition that these 2 signatures were written *after* the text was printed. This conclusion was based on the fact that the blue fluid ink used to write the questioned signatures would have been expected to penetrate the toner incompletely at each of the

intersecting points if the signatures had each been written after the text was printed on the paper.

Ongoing Research

The front and back of each test sheet will also be examined using the Electrostatic Detection Apparatus (ESDA), the Video Spectral Comparator (VSC), and Raman and Surface Enhanced Resonance Raman Scattering (SERRS) spectroscopy. The purpose is to determine whether these techniques assist in establishing the sequence. Similar tests for both sequences will also be undertaken using a variety of different laser printers and photocopiers (including poor quality products), different speeds and pressure of drawing the ink lines, and different time intervals between the writing of the ink and printing of the toner (and vice versa).

Further work will also be undertaken with respect to the presence or absence of specular reflectance for the intersections of ink *after* toner using various combinations of magnification and lighting. Blind tests will be undertaken and administered to other examiners.

References

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Determining the Sequence of Original Ink Writing and Toner Printing

Brand/Model of Pen	Color	Absorption	Specular Reflectance
Artline 200 Fine 0.4 (fiber tip)	blue	P	no
Artline 200 Fine 0.4 (fiber tip)	black	P - very little	no
Artline 200 Fine 0.4 (fiber tip)	red	P - some almost C	no
Artline 200 Fine 0.4 (fiber tip)	pink	P	no
Artline 200 Fine 0.4 (fiber tip)	purple	P	no
Artline 200 Fine 0.4 (fiber tip)	green	P - variable extent	no
Artline 200 Fine 0.4 (fiber tip)	brown	P	no
Artline 200 Fine 0.4 (fiber tip)	orange	P	no
Schwan Stabilo Point (fiber tip)	blue	P	no
Schwan Stabilo Point (fiber tip)	black	most P, some C green "halo" in vicinity	no
Schwan Stabilo Point (fiber tip)	green	P	no
Pilot Rollerball	blue	P - some close to C	no
Pilot Rollerball	black	P - very little	no
Pilot Rollerball	red	P - ink thick but patchy	no
Pilot Explorer (rollerball)	red	P	no
Ball Pentel (rollerball)	black	P - very little	no
Ball Pentel (rollerball)	red	P	no
Pentel Superball (rollerball)	blue	P	yes
Uni-ball Eye (rollerball)	blue	P	yes
Uni-ball Eye (rollerball)	red	P	yes
Uni-ball Micro (rollerball)	black	most P, some C	yes
Uni-ball Zirco (rollerball)	red	P - toner acts like a ramp, causes break in ink line after crossing	yes
Artline 210 (marker pen)	black	N	no
Artline Calligraphy (marker pen)	silver	N	whole ink line above toner
Artline 700 (marker pen)	blue	P - some close to C	yes
Artline 700 (marker pen)	black	P	yes
Artline 700 (marker pen)	red	C	yes
Artline 700 (marker pen)	green	C - some possibly P	yes (possible optical illusion)

Table 2. (continues)

Brand/Model of Pen	Color	Absorption	Spectral Reflectance
Pentel Maxiflow Permanent Marker	blue	C	yes
Pentel Maxiflow Permanent Marker	black	C	yes
Pentel Maxiflow Permanent Marker	red	C	yes
Pentel Maxiflow Permanent Marker	green	C	yes
Stabilo Boss (highlighter)	blue	P	no
Stabilo Boss (highlighter)	dk pink	P	no
Stabilo Boss (highlighter)	lt pink	P	no
Stabilo Boss (highlighter)	orange	P	no
Stabilo Boss (highlighter)	yellow	P	no
Stabilo Boss (highlighter)	green	P	no
Stabilo Boss (highlighter)	turquoise	P	no
Stabilo Boss (highlighter)	purple	P - very little	no
Pentel Hybrid Rollers	blue	most P, some C	residue above toner
Pentel Hybrid Rollers	purple	P	as above
Pentel Hybrid Rollers	green	P	as above
Pentel Hybrid Rollers	pink	P	as above
Pentel Hybrid Rollers	orange	P	as above
Pentel (gel)	purple	P	as above
PaperMate Gel Stick	purple	P	as above
Jimnie Gel	blue	P	no
Jimnie Gel	pink	P	no
BIC (ballpoint)	blue	P and N	no
BIC (ballpoint)	black	P and N	no
PaperMate (ballpoint)	blue	N	no
PaperMate Flexgrip (ballpoint)	blue	P and N	no
PaperMate Flexgrip (ballpoint)	black	N	no
PaperMate Replay (ballpoint)	blue	N	no
PaperMate Replay (ballpoint)	black	N	no
PaperMate Kilometric (ballpoint)	blue	P and N	no

Table 2. (continues)

Determining the Sequence of Original Ink Writing and Toner Printing

Brand/Model of Pen	Color	Absorption	Spectral Reflectance
Staedtler (ballpoint)	purple	P	yes
Staedtler Stick (ballpoint)	blue	P and N	no
Staedtler Stick (ballpoint)	red	P and N	no
Pilot BP-S (ballpoint)	black	N	no
Faber Castell (ballpoint)	blue	N	no
Faber Fix (ballpoint)	blue	N	no
Faber Fix (ballpoint)	black	N	no
Faber Fix (ballpoint)	red	P	no
Penline (ballpoint)	purple	N	no
Luxor Ranger (ballpoint)	blue	P and N	no
Artic (ballpoint)	blue	N	no
Artic (ballpoint)	black	N	no
Wilson Sly 400 (ballpoint)	red	P	no

Table 2. Observations in accordance with the classifications "C," "P," and "N" for the appearance of the ink line at intersections for the sequence of ink *after* toner.