

Spring 1963

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### Recommended Citation

Linton Godown, Sequence of Writings, 54 J. Crim. L. Criminology & Police Sci. 101 (1963)

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## SEQUENCE OF WRITINGS

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It is frequently of the utmost importance to determine, if possible, which of two touching writings was last written. Solution of sequence problems may relate directly to the issue of authenticity or may on the other hand affect the issues only indirectly; such as to confirm or refute testimony of alleged eyewitnesses and thus give some insight into their reliability with regard to other matters testified about.

Many scientists have pointed out, observations are made in the light of experience. As Goethe put it, "We see only what we know". Thus experiments with writing carried out with many similar and diverse materials under known conditions provide the essential experience background which permits recognition of clues to sequence encountered in actual problems. To interpret any available clue to writing sequence and grasp its significance requires a "prepared mind".

As with many other aspects of writing, the examiner who expresses an opinion regarding the sequence of writings, which is not based on extensive first-hand experiences and observations, may be inaccurate and invites possible embarrassment. Many experiments, using various writing materials, stroke sequences and surrounding conditions, should be undertaken and the results carefully studied. In many instances it is instructive to observe the actual behavior of writings in crossing of lines under considerable magnification as the writing takes place. A variety of conditions will be found to sometimes but not invariably accompany specific writing sequences. Only the discovery of similar concrete evidence in actual problems justifies forming and expressing an opinion regarding writing sequence.

Extensive experiment with test material is sure also to establish that definite physical indications of writing sequence are not invariably present. Even though two writings touch at several points,

it is not unusual to find that most points of contact provide no reliable evidence of the writing sequence. It logically follows that in dealing with any specific problem, failure to discover concrete evidence of sequence of one of two possibilities does not prove that the sequence was the other of the two possibilities. The folly of drawing definite conclusions from and attempting proof of a negative proposition is well known. An opinion regarding order of writing to be sound must be based on definite, demonstrable evidence and not the failure to observe evidence. If no definite indications are found, the answer is "I don't know", or "No opinion is justified". Natural, logical writing sequence should be assumed; and only contradicted when definite conclusive physical evidence of unnatural sequence has been discovered. Impressions of sequence not subject to recording and demonstration to others should be disregarded.

### EXAMINATION PROCEDURES

The most useful techniques at the disposal of the document examiner are observational. Various viewing aids from simple magnifiers to elaborate microscopes may be used. By far the most useful optical aid is the stereoscopic microscope. With some problems its utility may be extended by abandoning the vertical viewpoint customarily used in favor of observing the crossing at an angle. This is easily done using hand magnifiers but with the microscope this technique requires either one with an inclination joint or the construction of some sort of special sloping stage.

For most problems, magnifications of less than 50 $\times$  prove the most useful. Only an occasional problem will require the use of higher powers. On rare occasions the shallow depth of field of higher power objectives of the monocular micro-

scope may be of assistance in estimating depth of indentations or position and thickness of coatings.

Lighting control sometimes aids greatly in accurate interpretation of some conditions encountered. The familiar incident illumination with facilities for control of intensity and direction are those of the greatest usefulness. Many styles of commercial microscope illuminators are appropriate. The more concentrated raw light sources are frequently preferred to the broad diffused light types as delicate evidences of sequence are sometimes lost under diffused shadowless lighting. Such lightings tend to reduce both visual contrast and color saturation. Discrimination of fine detail is generally improved by high level lighting.

An interesting application of the 2-lamp fluorescent lights attaching directly to the microscope is to fit them with lamps of differing color, i.e., one blue and one green. The resulting dual color illumination enhances stereo effects in some instances of line crossing examination.

Observation of surface texture and irregularities may be improved by use of low-angle, grazing illumination. For psychological reasons, interpretation may be improved by illumination from the upper left of viewing position. With some classes of sequence problems, specular reflection (the mirror-like reflections from the surface) is essential.

Experience indicates that transmitted light occasionally offers assistance in specific situations. Except in rare instances, ultraviolet fluorescence or infrared radiation have so far not proved useful in examining writing sequence problems.

Occasionally, difficult illumination problems can be met by use of a concentrated light source which is adjustable in position from nearly horizontal to substantially vertical positions. With infrequent problems, the incident illumination controls possible at high magnification, such as are obtained through the use of Leitz Ultropak equipment, may prove useful.

Color filters have occasionally found use in sequence examinations. Polarized light has been found particularly helpful. When the area of contact of writings is illuminated by a specularly reflecting beam of plain polarized light, the surface reflections may be emphasized or eliminated according to the axis orientation of a polarizing viewing filter. With crossed axes the details of the subject are revealed without surface glare, which aids observation of some conditions. With axes parallel, specular reflection is emphasized by partial reflection of the diffused light from back-

ground so that surface reflections are thrown into higher contrast. These two conditions can be accomplished using a single circular polarizing filter placed in contact with the document. Both lighting and viewing take place through the filter. With its circular face down, all specular reflection is eliminated. With its circular face up, the opposite effect is obtained, specular reflection is enhanced and background subdued. Because of the inherent light losses of polarizing material, relatively strong lighting is required for best results.

Just as some examiners find it desirable to examine documents "from the four corners" it is well to observe each line crossing or other sequence problem from viewpoints along the axes of each of its lines from both directions. Sighting along the margins of each line under magnification may be most instructive. An inclined viewpoint is also frequently of some assistance in this type of inspection.

#### OPTICAL ILLUSIONS

Document examiners should be aware of the misleading optical illusion that the darker of two crossing lines appears to be uppermost whether it is or not. The illusion is readily demonstrated. It should stand as a perpetual warning, cautioning against reliance on superficial appearance or "impressions" in commenting on sequence of writings.

Scientific American, May 1962, contains an article by Ivo Kohler "Experiments with Goggles". In it he describes "color-stereo" effects, and depth illusions are examined and explained. Such illusions may result from the design and construction of optical instruments or from inherent qualities of the normal eye. U-V fluorescence observed under magnification may exhibit this stereo illusion. Some fluorescing lines appear to stand out from the paper surface. The effect is enhanced by the tendency of fluid inks to dry with more dense deposits at margins than in central areas. This resembles conventional representations of the cylinder. The possibility of depth or stereo illusion should be recognized when interpreting observations in sequence problems.

#### PHYSICAL EVIDENCES OF WRITING SEQUENCE

Some classification of the aspects and qualities to be observed in writing which may offer some reliable indication of writing sequence is useful. Four broad classes of conditions may be encountered, as follows:

1. Disturbances in the paper of the writing

background, i.e., surface rupture, changed absorbcency.

2. Modification of first writing material brought about by the second writing or subsequent operations.
3. Inherent qualities of the subsequent writing.
4. Modifications of the subsequent writing because of the prior presence of the first writing.

The manifestation and the clues provided by these various significant aspects of the writings may be influenced and modified by many factors. Foremost among the many variables and modifiers are:

1. The particular combination of writing materials involved; papers, pens, pencils, carbon, etc.
2. The direction and speed of the writing movements, frequently readily determined by inspection of pencil and ball pen writing at high magnification.
3. The quantity of marking material deposited on the paper. Fraudulent writing is frequently the result of slow, deliberate movements resulting in unusually heavy ink deposits where fluid ink is involved.
4. Qualities of the writing instruments, pen nib condition, foreign materials, chipped pen ball, etc.
5. Pressures during the writing acts evidenced by indenting the paper surface.
6. The time interval between writings.
7. The writing background, its texture, absorbcency, folding, etc.
8. The rigidity, flexibility, or pattern of the writing support.

In examining any specific problem, evidence from several classes affected by variables may be discovered, or nothing of any real significance observed. In the list of specific clues to sequence to follow, many writing materials have been considered, such as:

#### *Handwriting:*

##### *Fluid Ink.*

- Nibbed pens.
- Ball, stylographic and lettering pens.
- Ruling pens.
- Brushes, felt and bristle.

##### *Dry Pigments.*

- Graphite pencils.
- Dye and pigment mixtures.
- Colored pencils.
- Wax crayons.
- Carbon paper impressions.

##### *Viscous Inks.*

- Dye and/or pigment mixtures.
- Liquid graphite.
- N.C.R. papers.

#### *Mechanical Writings or Operations:*

##### *Ink Impression.*

- Typewriting (fabric ribbon).
- Rubber stampings.
- Metal stamping.

##### *Carbon Impressions or Transfers.*

- Original
- Multi-copy.

#### *Perforations:*

- Pierced—Pins, staples, etc.
- Punchings—Hole (cancellation coding).
- Shredding, i.e., check writer.

#### *Embossing—Seal.*

#### *Folds or Seams.*

Almost any combination of writings or operations from this summary may be involved in a particular problem. Those most commonly encountered involve either two handwritten lines in contact, or a typewriting and a handwriting in contact. An occasional problem may arise which involves offsets or transfers of writing impressions. Appreciative knowledge of the ingredients, behavior, and interreactions of many writing materials is essential to intelligent interpretation of evidence of line sequences.

### CLUES TO WRITING SEQUENCE

#### *1. Background Conditions*

- a. Some fiber forming the paper surface may be dislodged, displaced, or distorted by one of the writing strokes in a way that demonstrates sequence. When observed, this usually has resulted from the sharp pen-point cutting and tearing away a fiber or bundle of fibers. Where the fibers carry a stain of the previously written line, this condition can be most persuasive.
- b. The depressions in the paper formed by the writing instruments may by continuity or interruption of wall or trough indicate sequence. Such conditions are likely to involve pen nib tracks or furrows left by split or ball pen points. Best observed by adjusting illumination so that walls or troughs are specularly reflecting incident light, conditions under which any discontinuity will be most easily seen.

- c. Rupture of paper surface by folding, embossing, punching, scratching, or cutting of pen nibs, staple or pin holes may affect its absorbency and local reaction with subsequently applied writing materials of several classes. Transmitted light may assist in detecting slight reactions of this type.

## 2. Modifications of First Writing

- a. The action of the tip of the writing instrument may serve as a burnisher or polisher of the existing writing. This effect is most likely in hand or machine carbon impressions where the original matt surfaced deposit is wax containing and easily polished by later ball or fluid ink pen action. Specular reflection is helpful.
- b. The continuous concentration of dye at the margin of a fluid ink line is interrupted by the action of the fluid of the subsequent writing redissolving and redistributing this marginal deposit dye. The continuity of marginal dye deposit is best followed using specular reflections.
- c. The soluble dye of the first writing is dissolved and dispersed or redistributed along the later line. This effect differs somewhat in appearance from the type of flow-out observed running from the later to the first written line. It has a more diffused appearance, lacking sharp margins, and should not be confused with the common flow-out type of clue.
- d. The dye of the first written line is redissolved by the subsequent writing and picked up by the blotter at the time of blotting of the second written line.
- e. Pigment or dye solids of the first written line are displaced by the action of the second writing. Barr reported observing this condition where the black pigment of a pencil line was dragged from its original site by a crossing red pencil line.<sup>1</sup> Similar conditions may occur with other pencil combinations or when a sharp pen point drags ball pen, pencil, or insoluble materials of a fluid ink away from point of original deposit.
- f. Grooves or stria running with a first written pencil line may show interruption by

subsequently written line. Specular reflection helpful with such problems.

- g. Where hole punching has produced a raised edge or burr on the side away from direction of punch movement, subsequent writing may affect the regularity of this burr to reveal sequence.
- h. The crust of ink forming an ink line may be sufficiently brittle to chip and flake off as the result of later folding of paper.

## 3. Aspects Inherent in Later Writing

- a. Continuous, uninterrupted grooves or stria in uppermost of two pencil strokes. Specular reflection is very useful for observing this condition. Caution is required in considering stria where one stroke is in ink as transparent ink may not affect stria over which it passes.
- b. Continuous, uninterrupted marginal dye concentration of uppermost fluid ink writing. Specular lighting, using the metallic surface reflections helpful, particularly in dealing with dark inks. Transmitted light is also of value at times.

## 4. Subsequent Writing Modified by Original Writing

- a. The running out or spreading of fluid ink into existing ink line. This effect may be very slight in some instances and it is helpful to observe crossing at an angle and in both directions along the length of each of the lines.
- b. Somewhat similar effects have been observed where the original writing may be rubber stamp, ball pen or typewriting containing hygroscopic materials affecting absorbency of paper. The subsequent fluid ink, particularly if laid down heavily, may spread within paper structure. As this is not solely a surface condition, transmitted light helps materially to discover condition especially with dark materials. See figure 1.
- c. With some typewriting and subsequent heavy fluid ink deposit, a similar flow-out effect may result from fluid following the type depressions, deeply embossed in the paper surface. Again transmitted light may prove helpful.
- d. Some writing materials such as pencil pigments, ball pen, and typewriting ribbon inks contain water repelling substances picked up by pen point to cause repulsion of aqueous inks. This effect is likely to be

<sup>1</sup> R. E. Barr, St. Paul, Minnesota, during a group discussion of sequence evidence at a meeting of the American Society of Questioned Document Examiners.

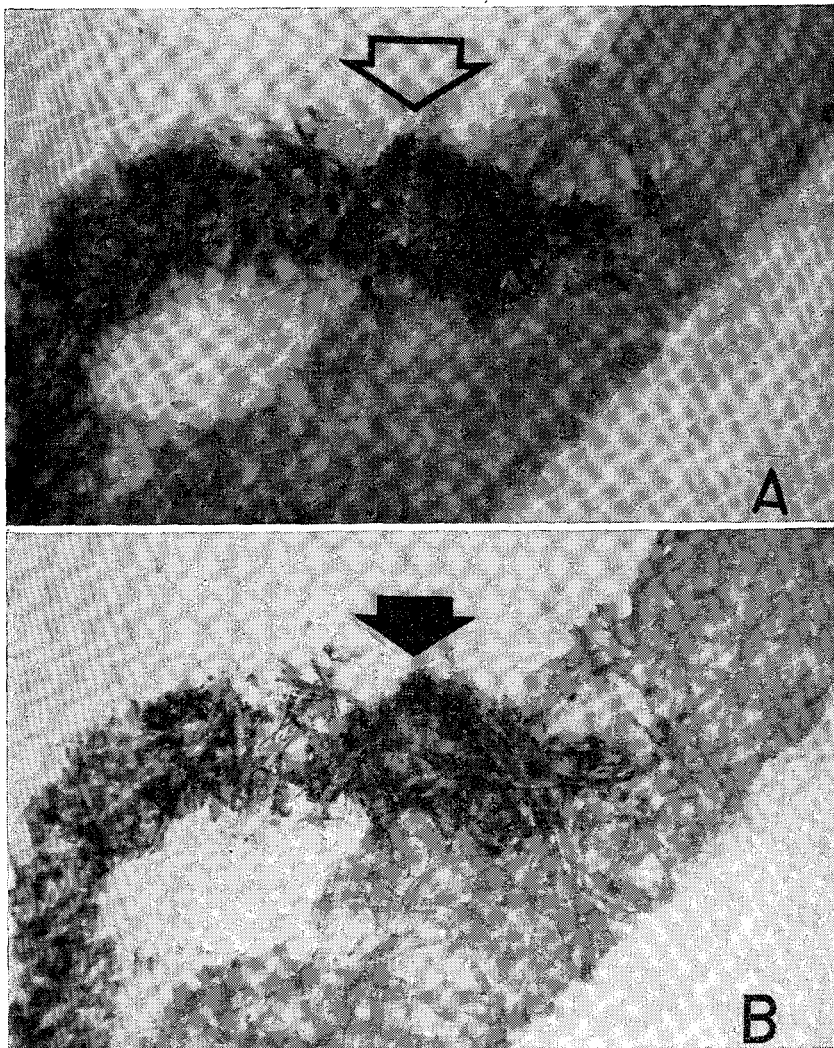


FIGURE 1

Showing fluid ink line touching upper part of typewritten letter "f". *A* By reflected light. Arrow indicates area where possible flow of lighter colored fluid ink into black typewriting impression cannot be observed with certainty. *B* Same area by transmitted light, showing a distinct flow of fluid ink into the existing type impression. This suggests the utility of transmitted light for inspection and illustration of this and similar classes of evidence. Note also the improved paper fiber definition afforded by transmitted light photography.

prominent on the side of intersection in the direction of pen movement. See figure 2.

- e. A similar discontinuity of fluid ink deposit may be observed within the confines of the typewritten impression. Specular and transmitted lighting are both helpful.
- f. Uniformity of line interrupted by depth of depression of first writing. Observed in some ball, fluid ink, typewriting situations as well as with embossing, printing, etc. The second writing does not reach down into the first made depression, there is a

"skip" caused by the depression (figure 3).

At times with ball pens and pencils the track is narrowed where it encounters the existing furrow. See figure 4.

- g. An increase in marginal concentration of dye of fluid ink at crossing over typewriting, as evidenced by specular metallic surface color reflected. The condition may be due to slower drying of the ink directly over a typewriting impression containing hygroscopic ingredients. Not all fluid inks, nor all typewritings, result in this condition.

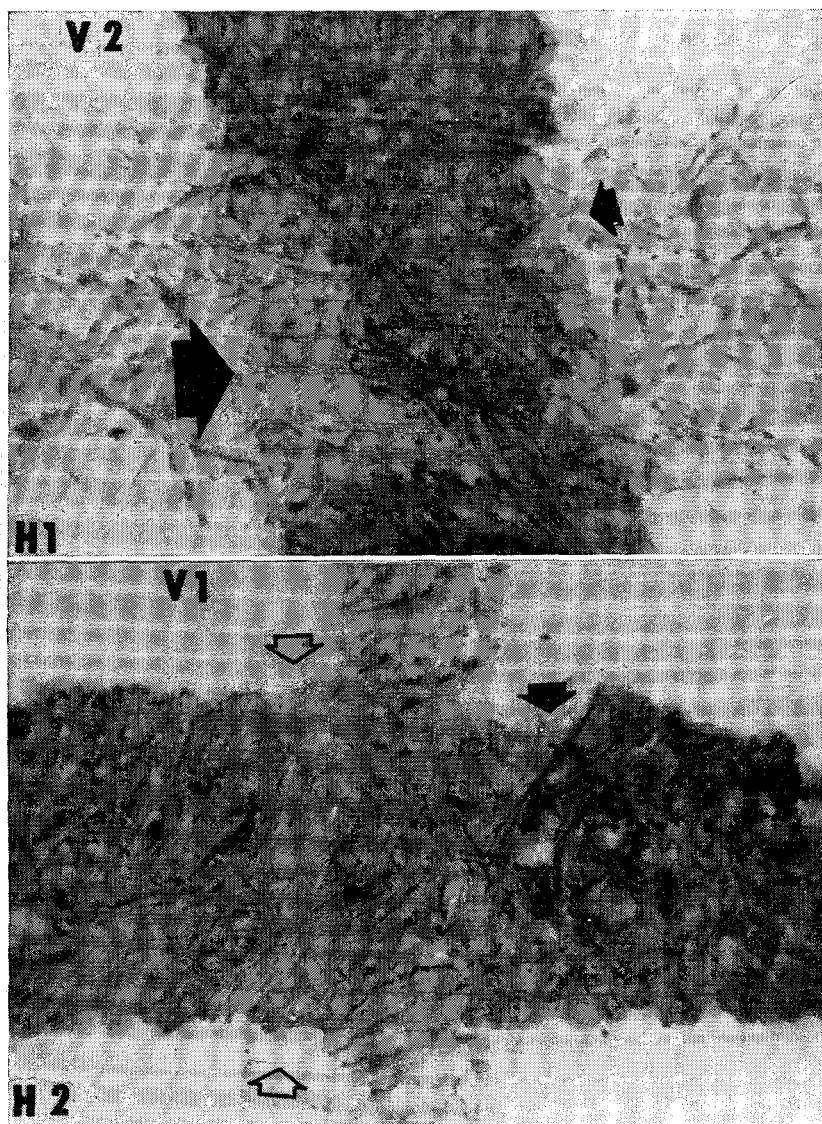


FIGURE 2

*Upper.* Waxy or fatty ingredients of the first written (horizontal) pencil line affect the later fluid ink line (vertical). Arrows point to distinct repulsion effects of the antagonistic water vs. oil writing materials. *Lower.* Similar repulsion effects involving ball pen ink (vertical, first written) and the horizontal black fluid ink line. Note gray area of little ink density to left of ball pen line (hollow arrows) and abrupt high density ink margin at right of ball pen line (solid arrows).

- Observation of this colored light may be aided by slight shifts from sharpest focus.
- h. The opposite of the phenomena of (g) has been observed, a lessening of marginal deposit over the typewriting. In some instances this has been observed as a slight diffusion resulting in a less sharp, well defined ink line margin than occurs on the paper at either side of the typewriting impression.
  - i. Deflection of writing instrument tip by presence of holes punched for accounting, cancellation, fastening, etc. purposes.
  - j. Uneven deposit of ink or pigment of last writing at crossing because of furrow of first stroke. This condition found with some ball pen and other writing is manifested by a tendency toward light marking at the near side of furrows and heavier inking at the far side of the existing stroke,



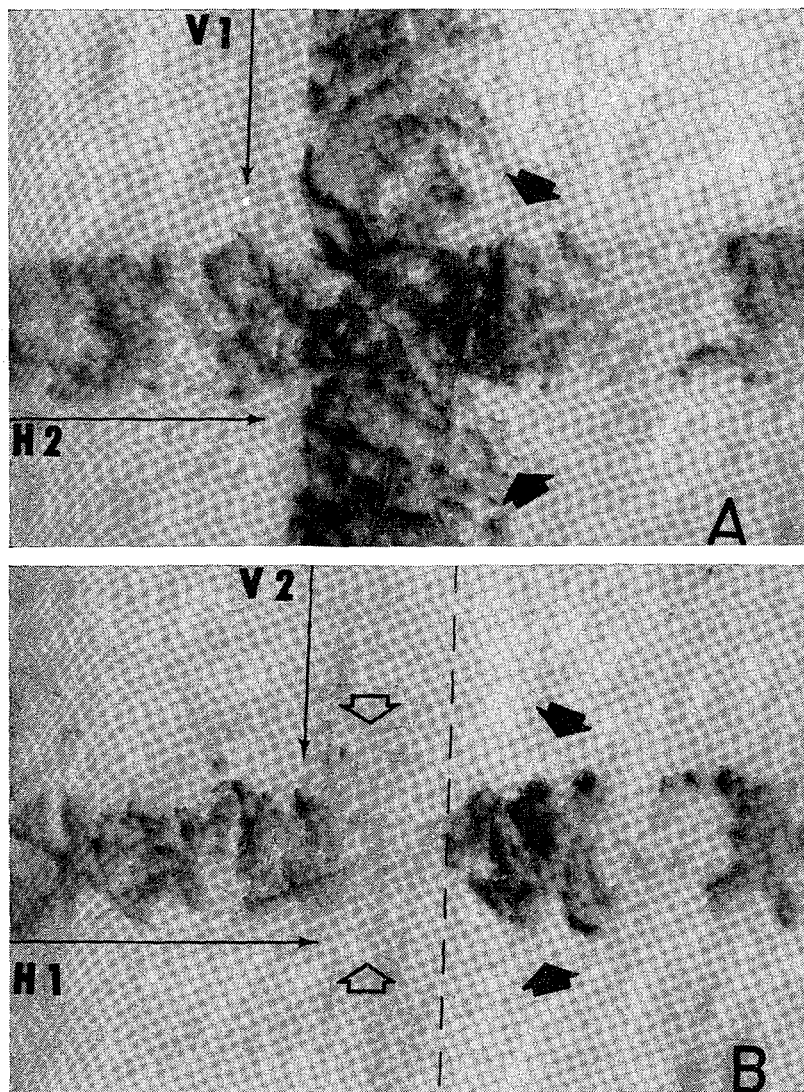


FIGURE 3

Crossing ball pen lines showing skip of trough of existing ball pen furrow (vertical) and piling up of ink at ridge on side toward which the ball pen moves. *A* Pigment in both lines. Light arrows show direction of movement, heavy arrows point to significant ink deposit. This condition is only occasionally encountered clearly defined and requires careful evaluation. *B* Dotted line indicates axis of uninked ball pen furrow. Hollow arrows point to area of skip while solid arrows indicate blob of ball pen ink deposited on far ridge of furrow by advancing pen.

as the ball or nib skips at the near side and strikes the slight ridge or wall more heavily as it moves on.

#### CLUES TO RELATIVE TIME OF WRITING

Occasionally conditions observed during writing sequence investigation may suggest something regarding possible time lapse *between* the touching writings. Typical significant qualities are:

- a. Maturity of ink of first stroke affecting its solubility in or other reaction with suc-

ceeding writing may be helpful, i.e., insoluble and unaffected by crossing stroke or, on the other hand, evident running out which took place prior to oxidation, might be indicative.

- b. The hygroscopic qualities of some slow drying rubber stamp, ball pen, and type-writing inks continue over some time, possibly days, under some atmospheric or storage conditions.
- c. The greasy repellant effect of some type-



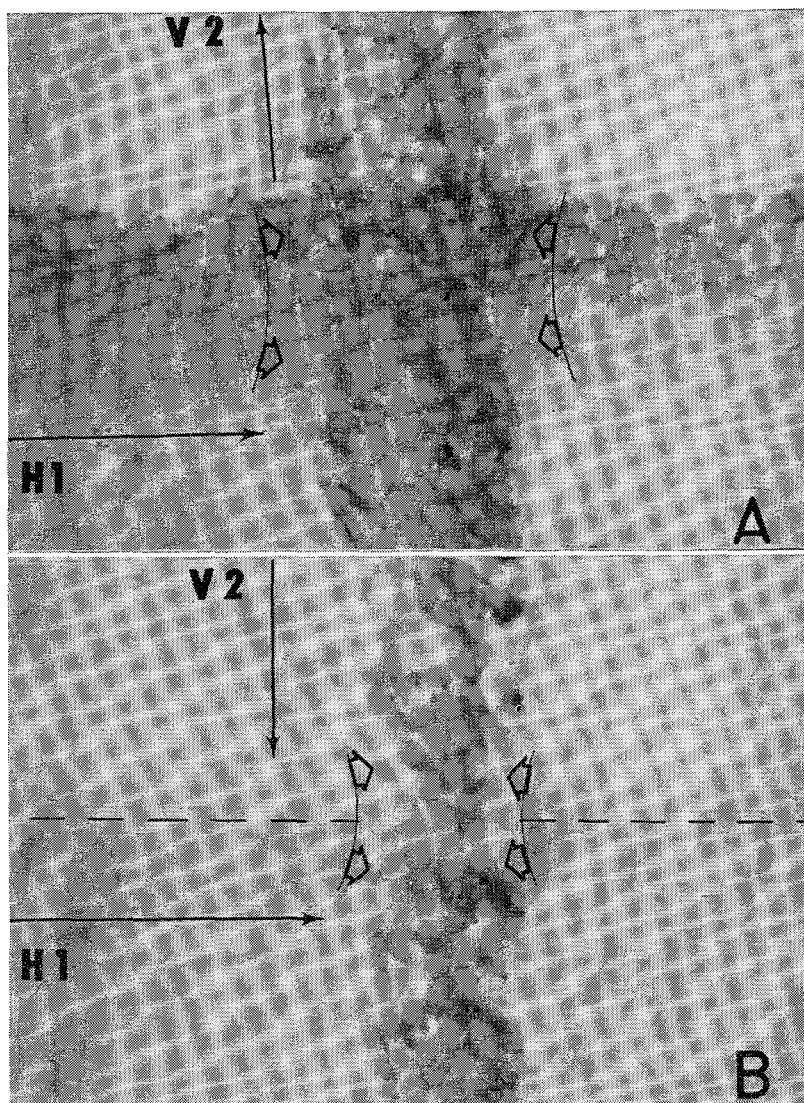


FIGURE 4

Illustrating narrowing of ink deposit of last written ball pen line at point of crossing existing ball pen furrow sometimes encountered. *A* Crossing ball pen line. Both lines show ink deposit but narrowing hour-glass-like deposit of last written line clearly shown. This condition results from the presence of the horizontal ball pen furrow. *B* Shows the same effect with horizontal uninked ball trace, (axis indicated by dashed line).

- writing impressions disappears with passage of time. Presence of repulsion would suggest relatively contemporaneous writings, at least not separated by weeks or months.
- d. Paper surface fibers, while soft and still moist, are more readily displaced by the friction of the crossing stroke.
- e. Some ball pen inks tend to penetrate or bleed through paper in time.

- f. Offset of ink to associated sheet may provide clue.
- g. Transfer of pigment or carbon coating comprising existing writings by subsequent writing. This may involve pickup of material from other sources by writing pressure as well as transfer away.

As with sequence problems, caution and reserve should dominate any expressions of opinion regarding relative time of writing. The reminder of

the lack of value of negative findings and the absence of criteria will bear repeating.

#### ILLUSTRATING SEQUENCE EVIDENCE

Special photographic methods are rarely of help in *determining* sequence. However, photography is of the utmost importance in recording and demonstrating the evidence of sequence to others. Usually, this requires photomacrography and photomicrography. Much ordinary black and white photography may result in disappointment as sequence criteria usually involve colored materials, fine detail and delicate, subtle interpretation of spatial relationships, sheen, texture, etc., suitably recorded in color. Transparency viewing devices are seldom equalled by other photographic methods for effective display of fine detail.

Most examiners agree that the most useful instrument for observing writing sequence conditions is the stereoscopic microscope. It seems to follow logically that the ideal method of illustrating what is thus observed would be stereo photography, color stereo photography. Although some few individuals may lack stereoscopic visual skills, their non-stereo interpretations of color transparencies seen by hand viewer would seem to at least equal, probably greatly surpass, their comprehension of the less realistic black and white print representations of the same material. Equipment for simplified color-stereo photography using stereo microscopes is readily available in commercial outfits or can be assembled from available camera, optical, and laboratory equipment.

#### CONCLUSIONS

Both experience and controlled experiments indicate that numerous physical conditions may provide reliable evidence of writing order or sequence. Concrete evidence is not invariably present. The stereo microscope accompanied by flexible incident and transmitted lighting provides the most useful examination equipment. Clues to sequence should be interpreted cautiously in the light of first-hand experiences. Negative evidence or failure to observe clues should be disregarded. Evidence not subject to review or demonstration to others must be considered with caution. Occasionally, conditions may justify cautious statements regarding lapse of time between touching

writings. Color-stereo photo-micrography appears to offer maximum promise as an illustrating medium.

#### AUTHOR'S NOTE

Special comment on the illustrations seems desirable in view of the unusual circumstances culminating in the present publication. Because of long standing dissatisfaction with black and white photographic methods applied to illustrating line sequence problems, an effort was made to use modern color films, stereography, and electronic flash to prepare more useful illustrations to demonstrate line sequence evidence. In a paper reporting on the results achieved at the 1962 meeting of the American Society of Questioned Document Examiners, numerous illustrations in color-stereo were prepared for display, either by projection or hand viewer. To accompany this paper on color stereo, an outline of line sequence evidence prepared several years ago was reviewed, expanded and brought up to date in the form of the present text. Because of the publication limitations, the original color-stereo illustrations were not appropriate, and it became necessary to resort to specially prepared black and white photographs, the process whose disappointing nature prompted the original investigation.

All of the accompanying black and white photomicrographs (20X) were made from exposures on 35 mm. Plus-X film. Leica Micro-Ibso equipment was employed, using a standard Spencer monocular microscope fitted with a 6X, 0.30 NA achromatic objective. The particular combination provides enlargement of 20X at the film plane. All lighting was by incident or reflected light with the exception of the single transmitted light illustration, figure 1B. Exposures were made using a single 480 Volt 5 Watt/Second electronic flash employing a lamp of special design positioned about 1" from the area photographed. The transmitted light exposure, figure 1B, was a 50 W/S flash. Power for the electronic flash is supplied by a circuit operating from ordinary power lines and permitting selection of energies from 2 W/S to 155 W/S per flash. Higher light values are achieved when needed by multiple flash. The flash equipment was designed and assembled particularly for use with daylight color film and color photomicrography, using stereo and other microscopes.