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New Dimensions in Infrared Luminescence Photography

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ABSTRACT: This study indicates that infrared luminescence examination can produce not only bright luminescence but also, in some instances, dark lines. They represent an additional criterion for differentiating similarly colored writing materials. These dark lines are obtained when the particular writing instrument is used on different paper bases and when the infrared luminescence photographs are made with different basic illumination properly filtered in the photographic process.

KEYWORDS: questioned documents, photography, luminescence

Infrared luminescence examinations have become a useful tool of the document examiner in problems of differentiating ink and at times in deciphering erased writing. A number of articles have been written and papers presented at technical meetings on the use of infrared luminescence and on modifications of techniques [*1-4*]. These discussions have considered the bright luminescence often encountered with inks, colored pencils, and other writing materials. The present discussion deals with a form of luminescence which to this writer's knowledge has not been reported upon, although undoubtedly some have observed it. It is a dark luminescence, which resembles a recording of infrared absorption produced by reflected infrared photography.

When referring to dark luminescence the writer is considering dark-line recordings in luminescence photography which cannot be obtained with direct or reflected infrared photography. One must be careful to distinguish between the two recordings, especially with setups in which infrared-absorbing material is recorded in the same photograph. There is danger of misinterpretation under these conditions. Thus a direct infrared absorption photograph must be used as a control.

Dark luminescence is not unknown in ultraviolet examinations, especially with erasures of iron-base ink effected by means of a bleaching agent. Examiners did not explore the reasons for it but only accepted it as one type of decipherment of the erased material [*5*]. This paper discusses a similar phenonenon with luminescence at a longer wavelength, that is, in the infrared range.

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Background

Dark infrared (IR) luminescence was first encountered several years ago during a study of red pencils [6]. With one group of red pencils, those whose color contained an appreciable amount of yellow, so that they bordered on orange, two of the pencils recorded black in an IR luminescence photograph. In a reflected IR photograph they failed to be recorded (Fig. 1). The luminescence unit consisted of a relatively light-tight wood box with a 10% copper sulfate solution contained in a flat-sided bottle approximately 38 mm ($1\frac{1}{2}$ in.) thick. The light source was a high intensity tungsten light (Sun-Gun). A recognizable amount of infrared leakage was present, and the immediate reaction was to suspect that low intensity IR radiation was the cause. A special setup with extremely low IR illumination and equally long exposure failed to bring about a recording of this entry by infrared absorption photography.

Subsequent testing of orange and yellow pencils, with an improved light-tight box that had aluminum sheathing over the plywood but that still recorded the presence of some low level IR, revealed a number of pencils that were recorded in various intensities of gray and black. (With the long exposures necessary for IR luminescence photography the bottle [filter unit] becomes warm on the inside surface of the box when the light source produces a good deal of heat. Elimination of this problem might be possible with a heat-resistant glass in front of the copper sulfate filter to reduce the heating of the filter.)

The study was undertaken to investigate further this dark luminescence phenomenon with different light sources. In other words, tests were designed to investigate whether the dark line results are actually the product of IR luminescence.

Procedure

A series of various colored pencils specimens was prepared with those colors which had previously produced dark line recordings.[2] These colors included orange, yellow, and light greens, especially those tending toward yellow green.

These specimens were photographed with the single high-intensity tungsten source (Sun-Gun) and with two mercury lamps (Westinghouse Par 38 H43/H44 KL 75-100). The light box and filter have been described. The illumination filter solution was 5% copper sulfate. Both lights were used with only a single filter, that is, the light was directed entirely from one side of the document. The mercury lamps generate a minimum amount of heat, but with this setup and light box both black pencil and black printers' ink are recorded. A Wratten 87 lens filter was used for all basic photographs.

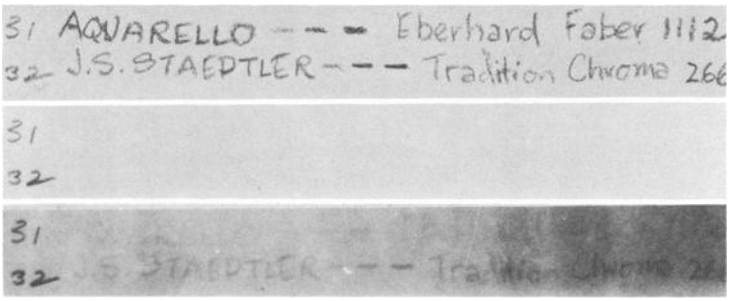

FIG. 1—*Photographs of two red pencils:* (top) *identification of the pencils,* (middle) *reflected IR, and* (bottom) *IR luminescence.*

[2] Some preliminary work done with red ball-point pens and porous tip pens indicates that under some conditions dark line recordings may be anticipated.

One additional test was performed. A luminescence photograph was made of the orange specimen with a Wratten 87C lens filter to eliminate all visible light.

Results and Comments

Reflected IR photographs of both the yellow and orange specimens reveal that all pencil leads were completely transparent to IR radiation. The IR luminescence photographs made with mercury lamp source revealed the following information. With writings on rag content paper containing a brightener, the yellow pencils showed 3 pencils with bright luminescence, 13 with dark recordings of varying intensity, and 2 without any luminescence (Fig. 2). The orange pencils on the same kind of paper revealed 4 bright luminescence and 8 dark recordings, some very weak, others of moderate intensity (Fig. 3).

The yellow pencils were also prepared on a cheap tablet paper (chemically treated wood pulp) without a brightener. Similar IR luminescence results were obtained, except that the two lines that failed to record showed a weak dark line. Since the filtered light illumination was controlled as accurately as possible it would appear that slightly different results can be obtained with different paper bases.

A change in light source for the luminescence photographs from mercury to high intensity tungsten lamps shows slightly different results, primarily in intensity of the luminescence (Fig. 4). The mercury lamp source produced slightly more intense dark recordings. The weaker results with the primary tungsten light source probably can be attributed to the presence of low intensity IR radiation resulting from the heating of the filter bottle and the cooper sulfate solution.[3]

With the selection of green pencils, two absorbed IR radiation and were recorded in a reflected IR photograph while the others did not. In the luminescence photograph these 2

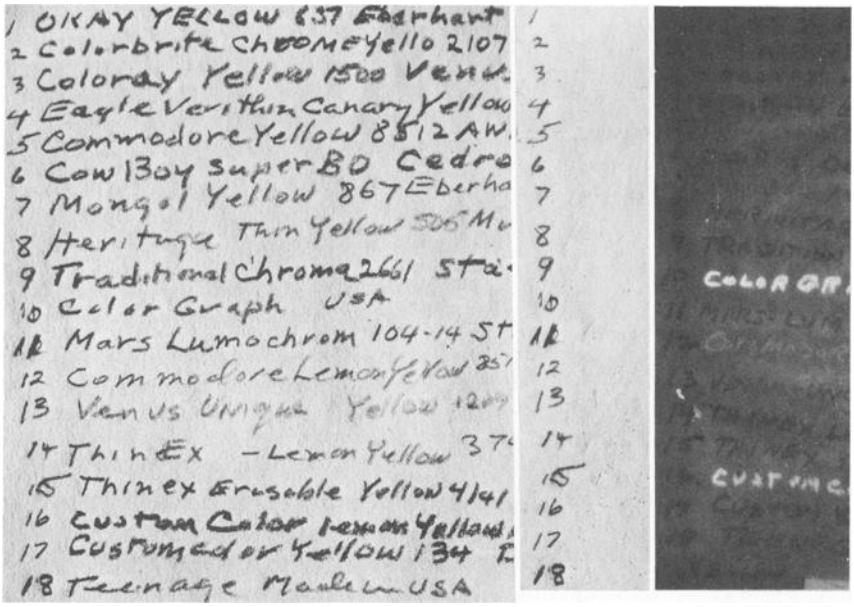

FIG. 2—*Photographs of 18 yellow pencils:* (left) *identification of the pencils,* (middle) *reflected IR, and* (right) *IR luminescence.*

[3] John Costain urges elimination of all low level IR in luminescence work to obtain the maximum advantages from the method (personal correspondence).

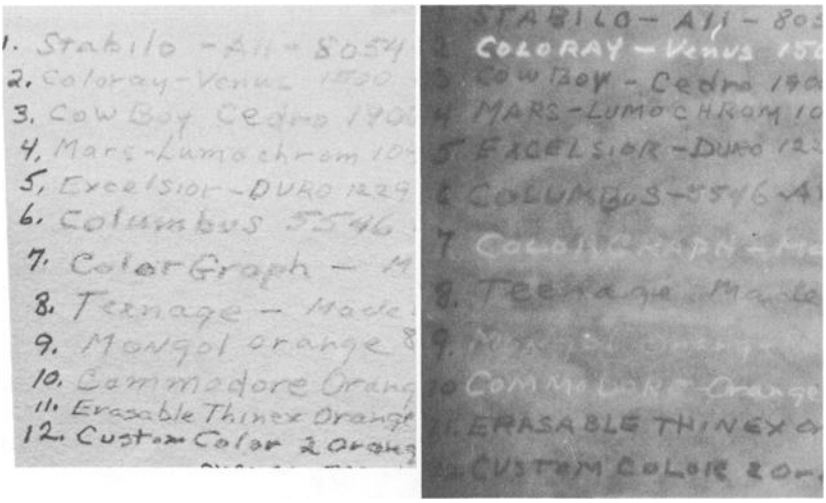

FIG. 3—*Photographs of the twelve orange pencils:* (left) *identification of the pencils and* (right) *IR luminescence.*

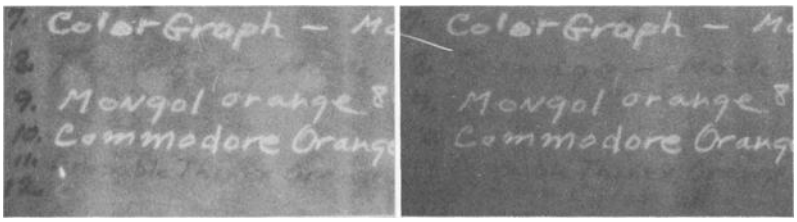

FIG. 4—*Orange pencils photographed with* (left) *tungsten light and* (right) *mercury lamps.*

and 7 others were recorded as dark lines, while another 3 out of the 13 pencils produced a bright luminescence (Fig. 5).

When the orange specimens were rephotographed with an 87C filter in place of the 87 the same dark and bright lines were obtained but the recordings were less intense (Fig. 6). Certainly, therefore, the dark line recordings are the result of IR luminescence, since the 87C filter eliminates all visible light, but both these and the bright luminescence wavelengths appear to be concentrated in the shorter IR wavelengths and possibly in the far red range. These wavelengths are transmitted somewhat more readily by the Wratten 87 filter than by the 87C.

From these various types of IR photographs one can conclude that the dark lines are the result of IR luminescence and not IR absorption. Previous tests involving equally long direct IR exposures to low level IR radiation failed to produce any recordings of dark lines with the two orange-red specimens. Likewise, use of the Wratten 87C filter, which cuts off beyond the visible red wavelengths, establishes that these dark lines are not a recording of visible red light.

It is also interesting that writing with the same instrument on papers of different composition can produce different IR luminescence results. In addition, if the particular light source

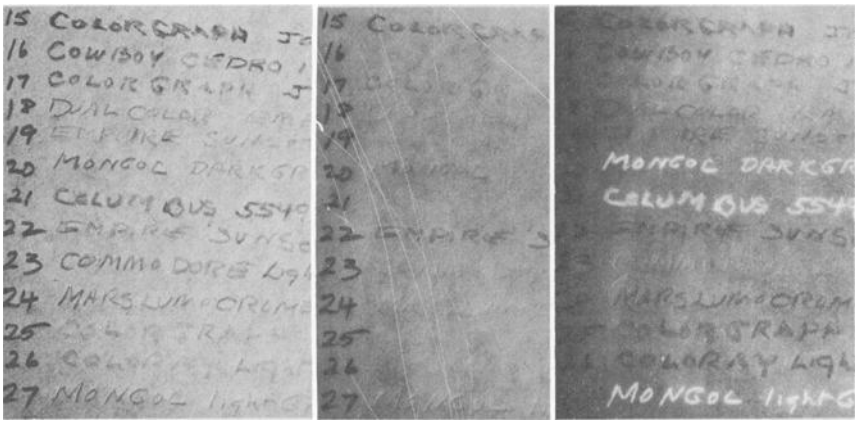

FIG. 5—*Photographs of 13 green pencils:* (left) *identification of the pencils,* (middle) *reflected IR, and* (right) *IR luminescence.*

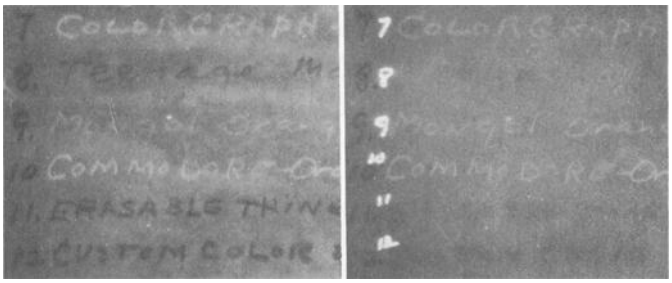

FIG. 6—*Photographs demonstrating IR luminescence with* (left) *a Wratten 87 filter and* (right) *a Wratten 87C filter. (The bright identifying numbers were added with a high luminescence red pencil.)*

can create low level IR radiation on the document one can expect less information in the final photograph.

All of the pencil specimens used for this study contained yellow. Because blues and reds which do not contain yellows do not produce dark luminescence, it could be presumed that a yellow dye or pigment used in colored pencil manufacturing caused the dark lines in IR luminescence photography, but there may well be other materials that will react in a similar way.

Addendum

During the discussion following the presentation of this paper, Gerald B. Richards of the FBI Laboratory suggested that the dark line recordings were the result of interaction of the paper luminescence and that of the writing material. If the paper did not show any luminescence, there would be no dark line recordings. He reported successful elimination of dark lines with a nonluminescent black paper.

Subsequently, two supplementary tests were made to investigate this theory further. Specimens of the yellow pencils on black paper were photographed for IR luminescence reactions. Not only were the black line recordings eliminated, but also those pencils that had

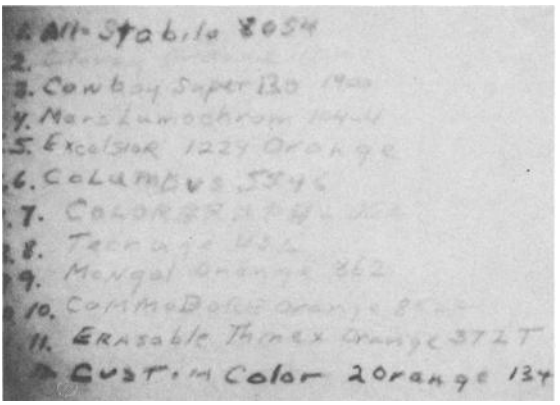

FIG. 7—*Infrared luminescence of orange pencils on yellow paper with high luminescence.*

shown bright lines in earlier photographs failed to be recorded. In other words, all luminescence was squelched by the light-absorbent quality of this paper.

A second test was run with the orange pencils on a sheet of yellow paper. The paper selected showed a very bright luminescence compared to the white papers previously used. The result was that all orange pencils, even those that had previously shown a bright luminescence, recorded as dark lines of varying intensity (Fig. 7).

These tests, especially the second, are certainly consistent with a conclusion that dark lines result from the relative luminescence intensity of the paper and writing material. The same pencil or ink may show a bright or dark line recording depending on the amount of luminescence emitted by the paper. Because of this apparent cause of the dark phenomenon such recordings may well be peculiar to document problems.

A final observation: If in the comparison of writing on two different papers one paper shows a significantly brighter luminescence than the other, the same ink or pencil may in one case show bright luminescence and in the other dark. In other words, examiners need to consider the reactions of both the paper and the writing material under IR luminescence testing before making any final determination from such tests.

References

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