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Ink Differentiation with Infrared Techniques

There are often questioned document problems in which alterations, additions, and obliterations have been made by visually similar inks. Such cases of forgery have been found in checks, passports, birth certificates, receipts, currency notes, lottery tickets, account books, etc. In the examination of such documents, an expert is often not interested in the complete composition of the inks involved, but is basically concerned with discriminating between these inks which are visually similar but chemically different in composition. He is thus interested in comparative study of the properties of various inks at large. A chemical analyst provided with a bottle of ink can determine the complete composition of an ink by several physico-chemical methods, but examination of ink on paper presents a much more complex and difficult problem [*1,2*]. For instance, about ninety-eight percent of the ink evaporates on writing and the residue is an extremely small quantity covering a very large surface. Ink writings, therefore, are either tested on paper or physically removed by special techniques [*1,3*]. This approach, apart from other basic handicaps, results in physical damage to the document in varying degrees depending upon the method used. Removal of ink from the document by solvents or physical punching of paper, followed by chromatography, electrophoresis, spectrophotometry, etc. are some of the other recent techniques which may give some specific information about composition and comparative identification [*1–5*]. However, these micromethods are cumbersome and require a good deal of expertise, apart from the basic disadvantage that the document is bound to be physically altered—even though to a small extent.

Nondestructive physical examination of inks on documents primarily concerns microscopic examination in visible light, followed by study using other invisible selective spectral regions, namely, ultraviolet and infrared. The characteristic behavior of ink writing under these conditions (which is also a function of their composition) offers valuable data regarding identity and specificity. These physical techniques had their beginning at the time of the introduction of optical filters [*6*], followed by photography in ultraviolet and infrared light. The latest techniques include using the infrared image converter and infrared luminescence which have further extended the scope of the nondestructive methods of ink differentiation. For studying the writings with inks available in India, a survey was first made of the available infrared techniques and the methods selected for application will be briefly discussed.

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Infrared Techniques

Thermofax Examination

Thermofax is a simple process of document copying wherein a heat sensitive emulsion-coated paper is used along with a strong filament light source [7]. The light radiations are only obstructed by the carbon or metallic constituent of the writing. Thus, the reproduction obtained is specific for writings involving carbon based inks or those containing iron and other metallic salts. Ball point inks and other dye based inks are eliminated in reproduction. This simple technique was useful in routine examinations of documents but it may not be applicable in all cases.

Dichroic Filters

Dichroic filters, consisting of a combination of glass/gelatine filters, basically transmit a large amount of the red region of the visible spectrum along with a relatively small amount of the blue-green region [17]. Ink writings when illuminated with light rich in red radiation and viewed through selected dichroic filters, may offer an image of red or purple color while the background is not affected at all. Ink writings which do undergo this change are in fact reflecting large amounts of red radiation which are, however, subdued along with their original color when viewed with a naked eye. When seen through a dichroic filter, a large amount of light in the blue-green region is subdued and transmission of red takes place predominantly. This simple technique could be usefully employed for preliminary examination. Godown [8], Packard [9], and Dick [10] have studied and recommended several combinations such as blue-green or green and yellow-orange filters which can be successfully applied. This technique though simple has limitations in actual use. For instance, a large variety of dichroic filters will be needed for every type of ink while individual visual response may itself differ [10]. This method also does not permit recording and recourse will have to be taken to other techniques discussed later.

Infrared Reflection Photography

The reflection (or absorption) of infrared radiations does not depend on the color of the material in visible light. Some of the writing materials, both fluid or ball point, reflect all infrared radiations and these inks are called transparent to infrared radiations. Blue-black (iron based) and certain ball point inks, however, absorb and reflect these radiations to varying degrees. When a photograph is taken with an infrared sensitive film using a strong source of infrared radiations for illumination, the final image is proportional to the extent of absorption of the infrared radiations by the ink involved. The resultant photographic evidence is often helpful in discovering forgeries.

Visual Observations with Infrared Image Converter

Visual examination with an infrared image converter has been made possible by the development of the caesium-silver cathode photoelectric cell, which is sensitive to infrared radiation [11]. The best response is in the range between 7000 Å to 12,000Å. The document is illuminated with a strong infrared radiation source and the light on reflection from the surface of the document falls on a lens system with an intermediate infrared filter. This image can be directly viewed as well as photographed on an ordinary film. This instrument has been found useful especially for preliminary examination of documents before taking infrared photographs although the field of vision is small [12]. However, the infrared image converter has not dispensed with the need of infrared photography because sometimes the visual image did not reveal the pattern which could be obtained through infrared photography or infrared luminescence.

Infrared Luminescence

Luminescence is reemission of energy at a longer wavelength of a part of the energy of an exciting radiation in the visible or near visible waveband, when that radiation has been absorbed by the chemical molecules. If the excitation is in the ultraviolet region of the spectrum, emission of energy is usually in the visible region and this phenomena is called ultraviolet flourescence [*8*]. If the exciting radiations are in the visible region, the emission of energy can be in the far-red and infrared regions which is termed as infrared luminescence. The term "infrared luminescence" has been used as there is experimental evidence of both fluorescent and phosphorescent properties being involved in this phenomena [*8*]. This new technique has been applied successfully for examination of various questioned document problems initially by using blue-green glass and gelatine filters [*8,13,14*]. However, 5 to 10 percent copper sulphate solution has been found to act as a superior filter and has been recently used by Ellen and Creer [*15*] and Shaneyfelt [*16*] for study of infrared luminescence of ink writings. The technique is basically simple because the resultant luminescence can be recorded directly photographically, on an infrared film. In practice, the infrared viewer (image-converter) or infrared photography or both may not show any difference, but infrared luminescence may be able to reveal a subtle difference in inks. The technique deserves to be routinely applied especially where other methods have failed to yield results. It has thus greatly enhanced the chances of deciphering obliterations, alterations, and overwritings including even erasures.

Experimental

This study has been undertaken in order to evaluate the application of the various infrared techniques discussed above as applied to inks available in India. The final objective is to select one or more methods for routine application in the examination of questioned documents involving erasure, overwritings, alteration, and obliterations. Seventy-one different types and makes of ink (royal-blue, blue-black, black, red, green inks, etc.; ball point inks; and typewriter ribbons) were collected. They were divided into eight major types (Types A–H) and are serially listed in Table 1.

White writing paper was cut into cards (4 × 6 in.) on which was written the sentence "Rupees one hundred only Rs. 100/–" with different inks. Five inks were used per card to give 5 similar lines and the serial number of inks was specified at the extreme left of each line on the card. Then on each line, the word hundred was obliterated, the word one was altered into four by adding the letter f, and the number 1 was changed into a 4, using a different type of ink whose number is indicated on the right side for each line on the card. The word *only* in each line was also erased with a rubber eraser to study if the erasures could be detected. The final card ready for examination was shown in Fig. 1. The selection of inks for purposes of obliterations and alterations was done by using various permutations and combinations, keeping in view the fact that alterations would only be done with inks which are visibly similar to the original. On the above basis 26 cards were prepared for all the inks divided into 8 basic types (A to H) in order to ensure that sufficient permutations and combinations are available for study (Table 2). However, in card No. 26 only, some red typewriter inks were also obliterated with blue black inks to study such cases.

Each of the twenty-six cards was then studied by the various infrared techniques.

TABLE 1—*Study of Indian inks by infrared techniques.*

D = Disappears
FV = Faintly Visible
V = Visible

FL = Faint Luminescence
L = Luminescence
NL = No Luminescence

Ink No.	Name and Details of the Inks	Thermofax Copying (I)	Color Through Dichroic Filter (Cobalt Blue + Wratten Filter No. 16) (II)	Infrared Reflection Photography (III)	Infrared Image Converter Visual Observation (IV)	Infrared Luminescence (V)
	Type A Royal Blue and Blue Black					
1.	Parker Quink (Washable) Royal Blue	D	Red	D	D	NL
2.	Pilot Royal Blue	D	Violet	FV	D	NL
3.	Waterman's Royal Blue	D	Red	D	D	L
4.	Sulekha (Special) Permanent Royal Blue	D	Violet	V	FV	NL
5.	Sulekha (Executive) Washable Royal Blue	D	Light Red	D	D	NL
6.	Sulekha (Brilliant) Royal Blue	D	Violet	FV	D	NL
7.	Weldon (Reserve) Royal Blue	D	Violet	D	D	NL
8.	Weldon (Fancy) Royal Blue	D	Violet	FV	D	NL
9.	Camel (Special) Royal Blue	D	Deep Red	FV	D	NL
10.	Camel (Deluxe) Royal Blue	D	Deep Red	FV	D	NL
11.	Swan Royal Blue	D	Violet	FV	D	NL
12.	Kores (Super-flo) Royal Blue	D	Violet	FV	D	NL
13.	Gulati (Deluxe) Royal Blue	D	Deep Red	FV	D	NL
14.	Eskema Royal Blue	D	Black	V	D	NL
15.	Kores Royal Blue	D	Violet	FV	D	NL
16.	Parket Quink Washable Blue Black	D	Violet	V	FV	NL
17.	Pilot Blue Black	D	Black	V	V	NL
18.	Waterman's Permanent Blue Black	D	Black	V	V	NL
19.	Sulekha (Special) Permanent Blue Black	D	Brown	FV	FV	NL
20.	Sulekha (Executive) Permanent Blue Black	D	Violet	FV	FV	NL
21.	Weldon (Fancy) Blue Black	D	Black	V	FV	NL
22.	Camel (Special) Permanent Blue Black	D	Violet	V	FV	NL
23.	Camel (Deluxe) Permanent Blue Black	D	Violet	V	V	NL

(*Continued*)

TABLE 1—Continued.

Ink No.	Name and Details of the Inks	Thermofax Copying (I)	Color Through Dichroic Filter (Cobalt Blue + Wratten Filter No. 16) (II)	Infrared Reflection Photography (III)	Infrared Image Converter Visual Observation (IV)	Infrared Lumines-cence (V)
24.	Swan (Deluxe) Blue Black	D	Violet	FV	FV	NL
25.	Swan Blue Black	D	Black	V	V	NL
26.	Kores (Super-flo) Permanent Blue Black	D	Black	V	FV	NL
27.	Kores Blue Black	D	Light Black	V	V	NL
28.	Gulati (Deluxe) Blue Black	D	Brown	FV	FV	NL
29.	Penman's Blue Black	D	Violet	V	FV	NL
	Type B Black Inks					
30.	Parker Quink Permanent	D	Red	FV	D	NL
31.	Waterman's Permanent	D	Black	V	V	NL
32.	Sulekha (Special) Permanent	D	Violet	V	FV	NL
33.	Sulekha (Executive) Permanent	D	Violet	V	FV	NL
34.	Weldon (Fancy)	V	Black	V	V	NL
35.	Camel (Special) Permanent	V	Black	V	V	NL
36.	Swan (Deluxe)	FV	Light Black	V	V	NL
37.	Swan	V	Black	V	FV	NL
	Type C Red Inks					
38.	Parker Quink Permanent	D	Red	D	D	NL
39.	Pilot Permanent	D	Red	D	D	NL
40.	Waterman's	D	Red	D	D	NL
41.	Sulekha (Special)	D	Red	D	D	NL
42.	Sulekha (Executive)	D	Red	D	D	NL
43.	Weldon (Fancy)	D	Red	D	D	NL
44.	Camel (Special)	D	Red	D	D	NL
45.	Swan (Deluxe)	D	Red	D	D	NL
46.	Kores (Super-flo)	D	Red	D	D	NL
	Type D Green Inks					
47.	Parker Quink	D	Brown	FV	D	L
48.	Pilot	D	Black	V	D	NL

(Continued)

TABLE 1—Continued.

Ink No.	Name and Details of the Inks	Thermofax Copying (I)	Color Through Dichroic Filter (Cobalt Blue + Wratten Filter No. 16) (II)	Infrared Reflection Photography (III)	Infrared Image Converter Visual Observation (IV)	Infrared Luminescence (V)
49.	Waterman's	D	Light Black	V	FV	FL
50.	Sulekha (Special)	D	Dark Black	V	D	NL
51.	Weldon	D	Light Black	FV	D	NL
52.	Weldon (Fancy)	D	Black	FV	D	NL
53.	Camel (Special)	D	Black	FV	D	NL
54.	Swan (Deluxe)	D	Black	V	D	NL
55.	Swan	D	Light Black	FV	D	NL
	Type E Ball-Point Inks (Blue)					
56.	Pilot	D	Red	D	FV	L
57.	Wilson (Jotter)	D	Violet	D	FV	NL
58.	Wilson (Documentary Tropicalised)	D	Red	D	FV	L
59.	Swan (Documentary Tropicalised)	D	Violet	FV	V	FL
60.	Ecko	D	Red	FV	V	FL
61.	Ambassador	D	Red	D	FV	L
62.	Fleet	D	Red	FV	FV	FL
63.	Upkar	D	Violet	FV	FV	L
64.	Delite	D	Light Black	V	FV	NL
	Type F Ball-Point Inks (Red)					
65.	Swan (Documentary Tropicalised)	D	Red	D	FV	NL
	Type G Ball-Point Inks (Black)					
66.	Swan (Documentary Tropicalised)	D	Black	FV	FV	NL
67.	Wilson	D	Black	FV	FV	NL
	Type H Typewriter Ribbons					
68.	Kores Black	D	Black	V	V	NL
69.	B.C.R. Black	V	Black	V	V	NL
70.	Kores Red	D	Red	D	D	NL
71.	B.C.R. Red	D	Red	D	D	L

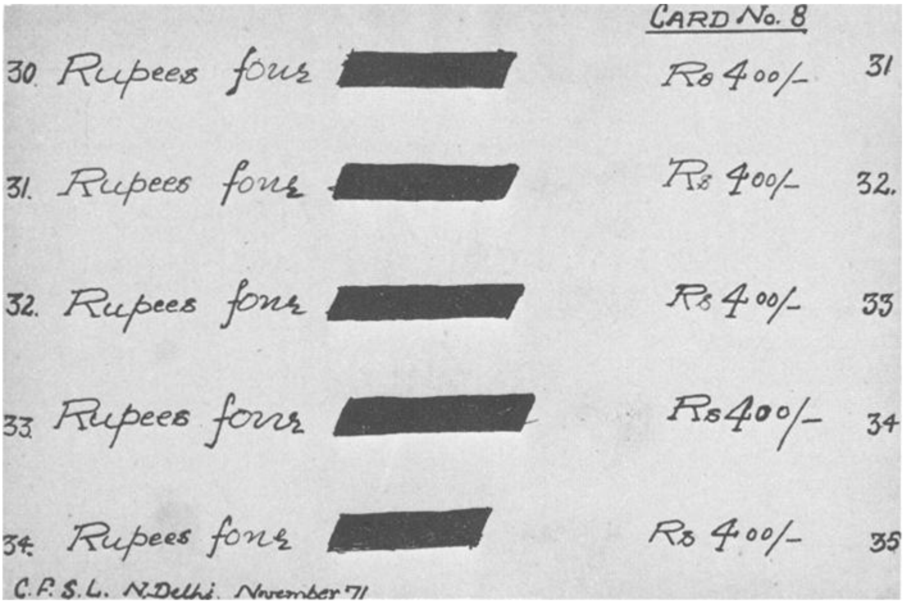

FIG. 1—*Final card showing obliterations, alterations, and erasures. Numbers appearing on left column indicate basic inks used in writing original text. Numbers mentioned on right column indicate ink used for subsequent additions and obliterations.*

Thermofax Copying

Each card was placed in contact with the thermographic paper and exposed to infrared light. The source of the infrared light was a filament lamp fitted inside this apparatus. The final copy was evaluated and the results recorded in Table 1.

Dichroic Filters

For analysis with dichroic filters three combinations, namely, (1) Kodak Wratten Gelatine Filter No. 16 plus 45; (2) No. 22 plus 44; and (3) No. 16 sandwiched between two cobalt blue glass sheets of 2 mm thickness, were used in all cases. Two ordinary tungsten bulbs of 100 watts each were used for illumination of the card. The combination of Kodak Wratten filter No. 16 [*17*] with cobalt blue glass proved to be the best and these results alone were recorded in Table 1. The technique could not be tried with other dichroic filters because these were not readily available.

Infrared Reflection Photography

Tungsten lamps were used to properly illuminate the card. Using a Linhof infrared filter and high speed Kodak 35 mm infrared film, the reflected infrared photographs were taken with an Asahi Pentax Spotmatic camera at f 16 and shutter speed ¼th of a second. The results are recorded in Table 1.

Visual Observations by Infrared Image Converter

Infrared image converter manufactured by Optische Werke Ernst Leitz G.m.b.H. of Wetzler, West Germany fitted with a halogen lamp was used for visual observation. The findings are recorded in Table 1.

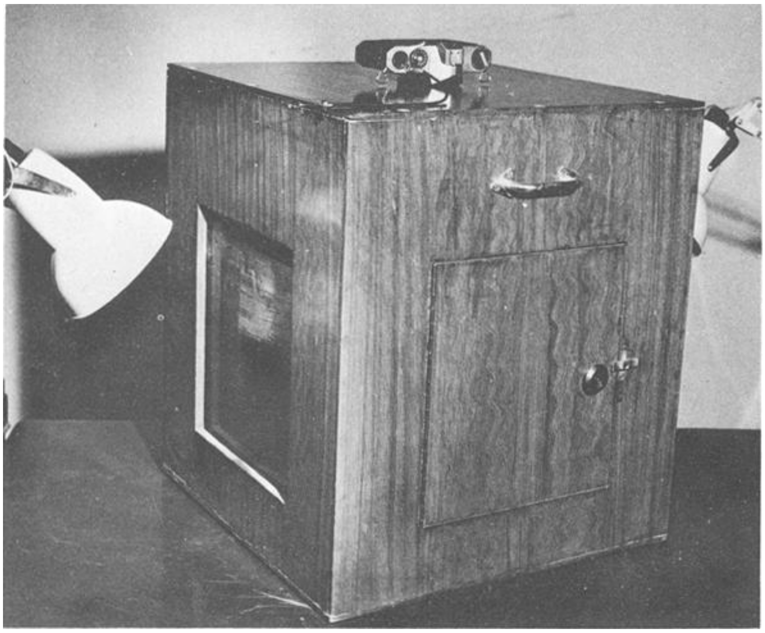

FIG. 2—*Infrared Luminescence Box showing glass cells, position of light sources, and the camera.*

Infrared Luminescence

A "Luminescence Box" as suggested by Ellen and Creer [*15*] was used although Shaneyfelt [*16*] has also recently suggested a circular glass cell for the same purpose. The size of the fabricated wooden box was 50 × 50 × 50 cm and it was light tight so as to completely shield the document from unwanted infrared and other light rays. Two glass cells 25 × 30 × 2.5 cm were fitted on two opposite sides of the box. The cells were filled with 10 percent copper sulphate solution. The source of excitation was two 250 watt bulbs, one on each side of the glass cells at a 45 deg angle as shown in Fig. 2. The card to be studied was placed inside the box and photographed on 35 mm Kodak high speed infrared film using a Asahi Pentax Spotmatic camera fitted in the center of the top of the box. A Linhof infrared filter was used to cut off the visible light and the aperture was kept at f 16 with an exposure time of 7 s. Sharp focussing was achieved initially with a red filter. The data from the pictures are recorded in Table 1.

Results and Discussions

The results of the analysis of 71 inks, broadly distributed into 8 categories by five basic infrared examination techniques, have been presented in Table 1. In Table 2, each of the individual 26 cards has been studied with respect to two visibly identical inks with a view to determining the best techniques which could be adopted for detection of alteration and obliteration in documents. The analysis of results given has indicated that excepting typewriter ribbon inks and three black fountain pen inks, all other Indian inks studied disappeared using the Thermofax copying process. It is evident that in cases using these types of inks alterations and obliterations can be easily deciphered. This effect has been shown clearly in Fig. 3 where black ink No. 30 had been used to obliterate the typed script.

TABLE 2—*Summary of infrared techniques applicable to different ink combinations.*

I—Thermofax Copying
II—Dichroic Filter (visual observation)
III—Infrared Reflection Photography
IV—Infrared Image Converter (visual observation)
V—Infrared Luminescence

Card No.	Basic Ink No. (vide Table 1)	Ink No. which has been used for Alteration and Obliteration (Table 1)	Summary of Methods to Detect: Alteration	Summary of Methods to Detect: Obliteration
Red Inks Types C and F				
1.	38	39	...	...
	39	40	...	...
	40	41	...	...
	41	42	...	...
	42	43	...	...
2.	43	44	...	...
	44	45	...	...
	45	46	...	...
	46	38	...	...
	65	38	IV	...
3.	40	65	IV	...
	42	65	IV	...
	44	65	IV	...
	45	65	IV	...
	46	65	IV	...
4.	70	65	IV	...
	70	39	...	...
	70	41	...	...
	71	44	V	...
	71	45	V	...
5.	70	40	...	...
	70	42	...	...
	70	43	...	...
	71	46	V	...
	71	38	V	...
Green Inks All Type D				
6.	47	55	II, V	...
	48	54	...	...
	49	53	II, IV	...
	50	52	II	...
	51	50	III, IV	...
7.	52	49	III	...
	53	48	II, III	...
	54	47	II, V	...
	49	52	III, IV	...
	55	50	...	...
Black Inks Type B				
8.	30	31	II, III, IV	...
	31	32	II, III	...
	32	33	...	...
	33	34	I, II, III, IV	...
	34	35	IV	...

(Continued)

TABLE 2—Continued.

Card No.	Basic Ink No. (vide Table 1)	Ink No. which has been used for Alteration and Obliteration (Table 1)	Summary of Methods to Detect	
			Alteration	Obliteration
9.	35	36	...	...
	36	37	I, IV	...
	37	30	I, II, III, IV	I, II, III, IV
	68	30	I, II, III, IV	I, II, III, IV
	69	35	I	I
Black Inks Type B on Red Typewriten Ribbons Type H and Blue Black Inks Type A				
10.	70	31	III, IV	...
	18	31	...	...
	19	33	II	...
	32	35	I, II, III, IV	...
	25	37	I, II, III, IV	...
Royal Blue and Blue Black Inks Types A and E				
11.	1	2	II, III	...
	2	3	...	...
	3	4	II, III, IV, V	...
	4	5	III, IV	III
	5	6	II, III	II
12.	6	7	III	...
	7	8	...	...
	9	10	II	...
	10	11	...	...
	8	9	...	...
13.	11	12	II, III	...
	12	13	II, III	...
	13	14	...	...
	14	15	II, III	...
	1	12	...	...
14.	16	17	II, IV	...
	17	18	...	...
	18	19	IV	IV
	19	20	II, III, IV	...
	20	21	II, III, IV	...
15.	21	22	...	...
	22	23	IV	...
	23	24	III, IV	...
	24	25	II, III, IV	...
	25	26	II, III, IV	...
16.	26	27	...	...
	27	28	II, IV	...
	28	29	II, III, IV	...
	29	23	III, IV	..
	26	16	...	...
17.	1	18	II, III, IV	...
	2	19	IV	...
	3	20	II, III, IV, V	...
	4	21	II, III, IV	...
	5	22	III, IV	...

(*Continued*)

TABLE 2—Continued.

Card No.	Basic Ink No. (vide Table 1)	Ink No. which has been used for Alteration and Obliteration (Table 1)	Summary of Methods to Detect: Alteration	Summary of Methods to Detect: Obliteration
18.	6	23	II, III, IV	. . .
	7	24	. . .	. . .
	8	25	II, III, IV	. . .
	9	26	III, IV	. . .
	10	27	IV	. . .
19.	11	28	. . .	. . .
	12	29	III, IV	. . .
	13	16	III, IV	. . .
	14	17	III, IV	. . .
	15	18	II, III, IV	. . .
20.	57	2	IV	. . .
	58	3	IV, V	. . .
	59	4	III, IV	. . .
	60	5	II, IV	. . .
	56	1	II, IV, V	. . .
21.	61	6	II, IV, V	. . .
	62	7	II, IV, V	. . .
	63	8	IV, V	II, V
	64	9	II, III, IV	III, IV
	56	10	II, III, IV, V	. . .
22.	57	11	II, IV, V	II
	58	12	II, IV, V	IV
	59	13	II, IV, V	IV
	60	14	II, IV, V	. . .
	61	15	II, III, IV, V	IV
23.	62	16	III, IV	. . .
	63	17	II, III, IV, V	. . .
	64	18	II, III, IV, V	. . .
	56	19	II, III, IV, V	. . .
	57	20	II, III, IV	. . .
24.	58	21	II, III, IV, V	. . .
	59	22	II, III, IV, V	. . .
	60	23	II, III, IV	. . .
	61	24	II, III, IV, V	. . .
	62	25	II, III, IV	. . .
25.	63	26	II, III, IV, V	. . .
	64	27	II, III, IV, V	. . .
	56	28	II, IV, V	. . .
	57	29	IV	. . .
	58	1	II, III, IV, V	. . .
Royal Blue and Blue Black Inks Type A on Typewriter Ribbon Type H				
26.	68	1	I, II, III, IV	I, III, IV
	69	5	I, II, III, IV	I, III, IV
	70	3	V	. . .
	71	20	II, III, V	. . .
	68	16	I, II, III, IV	I, II, III, IV

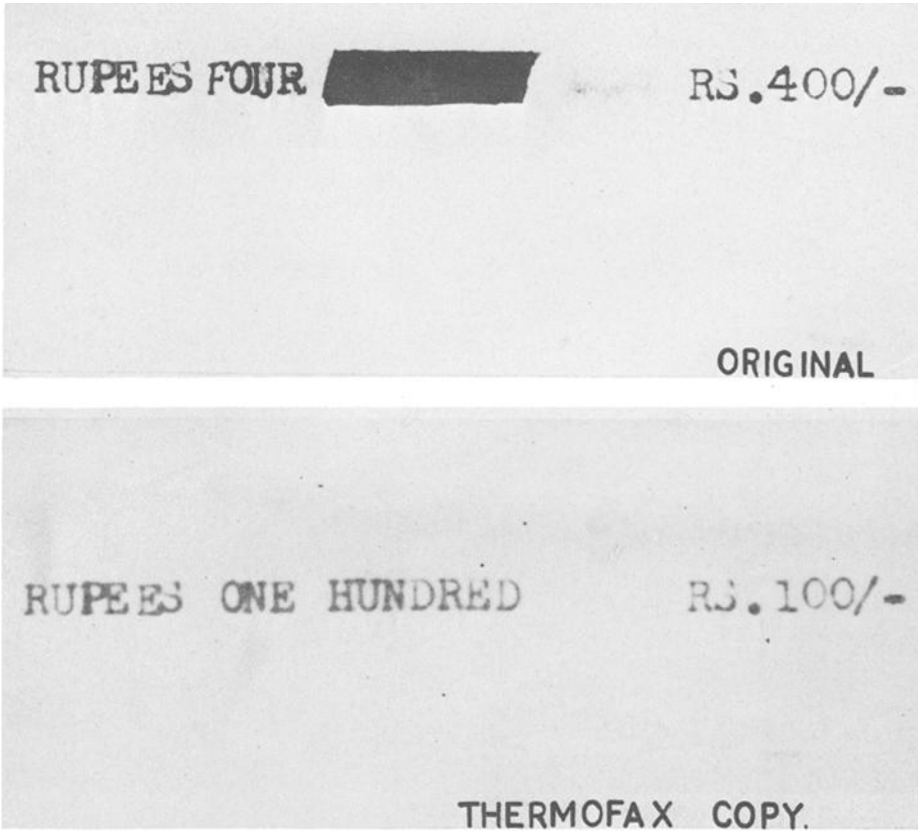

FIG. 3—*Decipherment of obliterated and altered typewritten material by Thermofax copying.*

However, this process is less sensitive in comparative differentiation of inks as evidenced by its comparison to other techniques such as visual observation through an infrared image converter.

As regards infrared reflection photography, various blue, blue-black, black, green fountain pen inks and ball point blue inks have given opaque to transparent images depending upon their chemical composition. All categories of red inks were found completely transparent. However, black fountain pen inks were completely opaque as were black typewriter ribbon inks. This technique has been equally successful in detecting alterations and obliterations in a number of cases as indicated in Table 2. Numerically speaking success was achieved in 45 percent of the cases of alteration and 5 percent of the cases of obliteration. A typical case is shown in Fig. 4 involving ink No. 37 for basic writing and ink number 30 for making additions and obliterations.

In this study, however, it was found necessary to use infrared film of superior quality in order to ensure satisfactory results. Photographic work connected with the study also made it evident that considerable expertise and care is required in obtaining the suitable photographic evidence. For infrared reflection photography and infrared luminescence photography, a decrease in exposure and an increase in development time of infrared films is recommended. Since infrared films are low contrast films, overdevelopment of

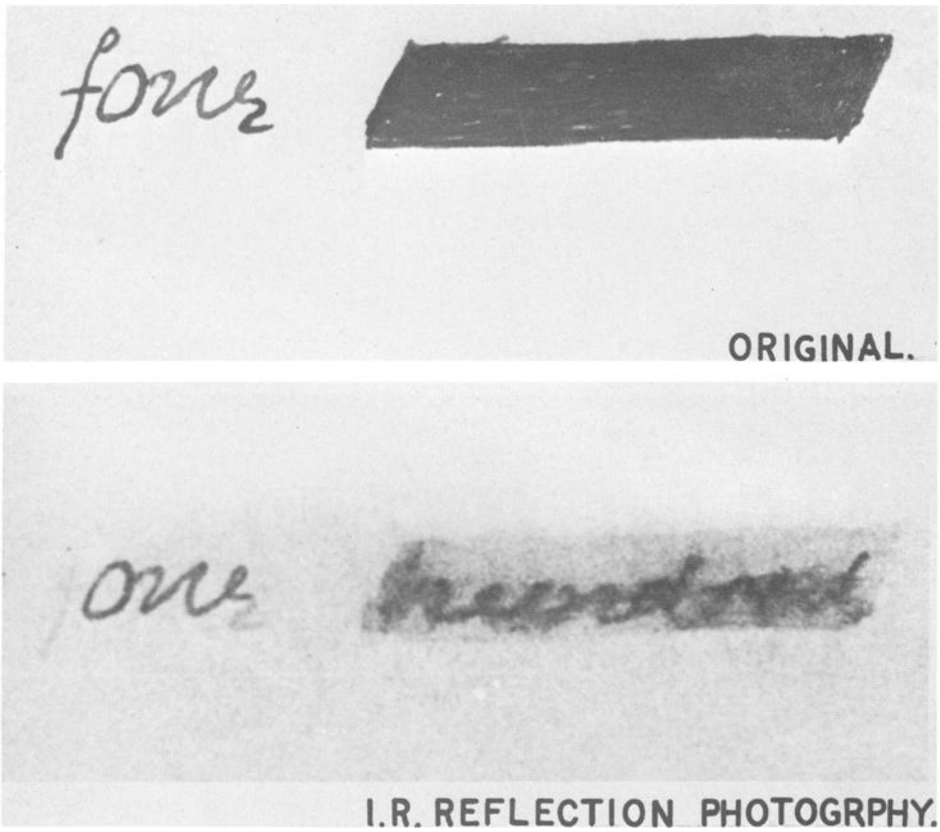

FIG. 4—*Decipherment of obliterated and altered handwriting by Infrared Reflection Photography.*

these films gives better contrast. However, too much development could also cause fogging and, consequently, decrease the contrast. The use of hardgrade paper may assist.

Theoretically, visual observation using an infrared image converter should have given the same results as were obtained using infrared reflection photography. However, some differences have been observed which are in keeping with previous observations [*16*]. For instance, red ball point inks were visible when viewed through an image converter although they completely disappeared in infrared reflection photography. Similarly, some differences were also observed in cases of blue, blue-black, black, and green fountain pen inks as well as in ball point inks. These differences generally concern the intensity of the image with respect to a number of inks as detailed in Table 1 under method 3. However, the visual observation using an infrared image converter has been found useful for preliminary examination of documents before undertaking photography by one of the recording methods.

Although infrared reflection photography and visual observation through an image converter was highly successful in many cases, this technique was not always applicable to inks which were otherwise very similar. Application of infrared luminescence technique by the simple procedure already described, gave highly successful results in some of the cases. For instance, one royal blue and two green fountain pen inks showed the desired luminescence effects. A red typewriter ribbon ink No. 71 which completely disappeared when examined by thermofax copying, infrared reflection photography, and visual observation through an image converter did show luminescence. In 23 percent of the cases, the infrared luminescence was applicable as reported in Table 2. Specific use of this technique was justified in 4 percent of the cases where other methods were not useful at all. This additional property of luminescence associated with an ink could, therefore, be taken advantage of for deciphering additions, alterations, and obliterations. Although the technique may not be equally useful in all unknown cases, it is quite evident that it should be routinely used for the detection of document forgeries when the other normal ultraviolet and infrared techniques have failed to give the desired results. A typical case in which infrared luminescence was useful in detecting alterations is illustrated in Fig. 5. This involved ball point ink No. 62 for basic writing which was altered with ink No. 26.

As indicated already, only one dichroic filter was found to be most suitable for examination of inks on 26 cards. Most of the inks changed in color varying from black to red on visual observation. This made it possible to differentiate between two visibly similar inks by the help of this simple device. However, this examination could not be transferred to photographic evidence and did involve some personal factors of vision. All the same, dichroic filter examination was found successful in 47 percent of the cases involving alterations while it supported the infrared photography and infrared luminescence in 31 percent and 17 percent of the cases, respectively. It could best serve as a preliminary screening procedure.

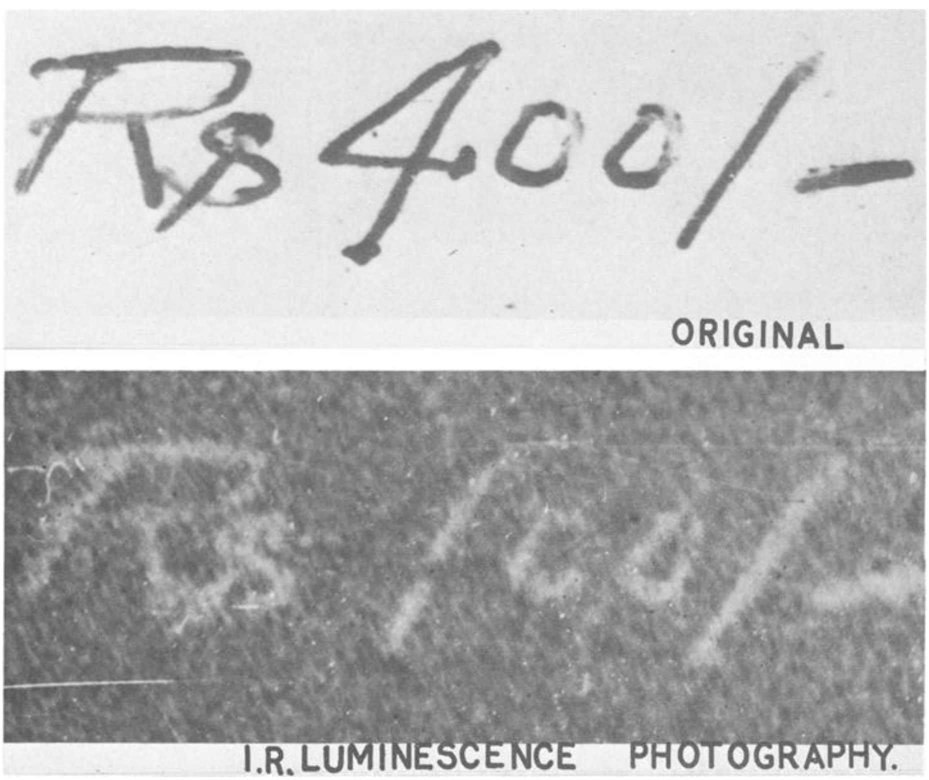

FIG. 5—*Decipherment of original figures using Infrared Luminescence.*

Conclusion

From the present study involving 71 Indian inks covering virtually the entire range of standard products available on the market, it was evident that nondestructive infrared techniques could be employed with great advantage for solving specific problems of document examination. This approach was specially useful when used with other established techniques of ultraviolet light examination, macro-photography, and photography using colored filters. In the case of 130 combinations of visibly similar inks studied by 5 different infrared techniques, at least 70 percent of the alterations and nearly 10 percent of the obliterations could be successfully detected by one or more of these techniques. Forgeries involving fountain pen inks on typewritten, printed, or carbon based ink writing were easier to detect. However, none of the methods employed afforded any assistance in deciphering the physical erasures. This aspect of the study is being further pursued. The study has also emphasized that even if preliminary examination with an infrared image converter and dichroic filters does not give the desired results, further study with infrared reflection photography and infrared luminescence should not be dispensed with. In fact, these two techniques applied in this order, would very often offer valuable clues in case of forgery.

Summary

Relative merit of available infrared techniques have been assessed for differentiation of writings involving 71 samples of different inks available in India. Detection and decipherment of erased, altered, and obliterated ink writings and type writings have also been attempted with varying degrees of success by these methods.

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