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CENTRE CANADIEN DE RECHERCHES POLICIÈRES

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EDGE OF LIGHT
- OPERATIONAL ASSESSMENT

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TECHNICAL MEMORANDUM

Submitted by
Canadian Police Research Centre

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NOTE: Further information about this report can be obtained by calling the CPRC information number (613) 998-6343

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EXECUTIVE SUMMARY

The “edge of light” (EOL) technology was developed at the National Research Council - Institute of Aerospace Research (NRC-IAR). The technology was initially evaluated in the NRC laboratory (see technical memorandum TM-21 -95). As a result of this evaluation and the potential of “EOL” technology in the law enforcement community it was decided to have the RCMP Central Forensic Laboratory and the Revenue Canada Laboratory and Scientific Services Directorate to operationally evaluate the technology. This technical memorandum describes these two evaluations.

Appended to this technical memorandum is the NRC-IAR Fact Sheet and Tech Sheet entitled, “The Edge of Light™ Enhanced Optical NDI (Non-Destructive Investigation) Technique”.

SOMMAIRE

La technologie « edge of light » (EOL) a été mise au point au Conseil national de recherches - Institut de recherche aerospatiale (CNR-IRA). La technologie a d’abord été évaluée dans les laboratoires du CNR (voir le document technique TM-21 -95). Par suite de cette evaluation et compte tenu du potentiel de la technologie EOL pour les services de police, il a été convenu que le Laboratoire judiciaire central de la GRC et le Service des travaux scientifiques et de laboratoire de Revenu Canada évalueraient la technologie sur le plan operationnel. Le present document technique décrit ces deux evaluations.

Le document technique est accompagne de la fiche signaletique du CNR-IRA et de la fiche technique intitulée « The Edge of Light™ Enhanced Optical NDI (Non-Destructive Investigation Technique ».

“EDGE OF LIGHT - OPERATIONAL ASSESSMENT” - RCMP

INTRODUCTION

This report is a summary of application studies of the Edge of Light (EOL) technology to operational cases analysed at the Central Bureau for Counterfeits (CB4C) of the RCMP, Central Forensic Laboratory in Ottawa. The first prototype of EOL was introduced to CB4C in May 1996, it was tested for a period of six months. A second generation of EOL was presented to CB4C in May 1997 for testing for a period of also six months.

In a Technical Memorandum from the CPRC dated June 1995, different forensic applications were tested, ranging from tests on counterfeit money to handwriting indentations, altered credit cards and fingerprints - areas commonly examined by the RCMP document section. EOL technology appears to be a promising instrument.

POTENTIAL APPLICATIONS FOR EOL IN THE RCMP DOCUMENT SECTION

The main possibilities of the EOL technology are primarily in the capacity of the EOL to decipher and illustrate some types of alterations in specific cases. For example, in cases of bleached banknotes, the EOL technology could provide a “map topography” of the Intaglio printing of a genuine bleached banknote (i.e. a note that has been bleached and fraudulently reprinted to a higher denomination). Furthermore, the EOL could decipher cases of mechanical erasures of typewritten or handwritten information on travel documents such as passports. The EOL could also provide additional information (i.e. its “map surface reading” capabilities) that were not available through other apparatus such as the Video Spectral Comparator (VSC) or the ESDA.

EOL GENERATION I

Several tests of banknotes, travel documents and handwriting indentations were conducted with the EOL I. We quickly came to the conclusion that EOL I was more a demonstration of the EOL principle rather than a true forensic instrument. The results of the EOL I were limited by two main factors:

1) EOL I being a hand held scanning device rolling on a surface, images from EOL could be distorted by a deficient scanning movement. The thickness of a document created some problems in unequal surface. For example, biographical data are located on the first pages of a passport resulting into an unequal reading surface for the scanner (i.e. a few pages on one side of the booklet and several pages on the other side create a difficult scanning movement).

2) It was not possible in EOL I to adjust the slit reading angle of the scanner, in order to vary the band width of type edge zone of reading of EOL. Variations of the slit angle has proven to be a very significant factor of image optimization or reduction in its quality. For example, an adjustment obtained for the examination of printed matter would provide poor result in a handwriting case.

EOL GENERATION II

The presence of an inverted scanner on a flat surface was a major improvement of EOL II. The scanning movement was now mechanically performed and presented more consistency in the image quality (less distortion). The EOL II enabled also the possibility of adjusting the slit angle of the scanner and to obtain a control value of the height of the scanning head components. Slit angulation and height are important components for producing a quality image.

Forensic applications tested with EOL II

Several tests have been conducted from May 1997 to September 1997 of EOL II. We have concentrated our efforts in determining reliable setting for producing a good quality image for two categories of examination: printed material and handwritten alteration.

In illustration 1, differences of a fictitious banknotes printed in intaglio on top and offset at the bottom were successfully recorded by EOL at a specific setting. It was revealed that EOL II could generate a wide span of image quality but differences between offset and intaglio printing could be lost by an improper setting. EOL II must ALWAYS be used with calibration standards before conducting a formal examination. This process is necessary to determine the significance of differences or similarities (i.e. resulting of a difference in the comparison of two documents and not a result of a misadjustment of the EOL). Settings are very critical in EOL and should be recordable in order to provide full control and to give the possibility to redoing an examination under the same conditions.

Printing standard, erased writing standards, indented standards and embossed standards were developed to test the EOL II. Several experimentations in the determination of slit/height measurements were also necessary to obtain positive results. While some “key settings” appeared to be better for printed matters, other settings for indented writing material or different settings for mechanical erased information, it was not possible to categorize a specific setting to a specific type of alteration of examinations. A good quality image was obtained for mechanical erasure at a setting of 70/1 4/1 38, height 1.9075 while for a printed matter the best setting was 70/50/140, height 1.9480. But in other cases the same settings would provide poor results. It appears that the EOL will give its full potential when a “daisy wheel of settings” is systematically done for each case in order to determine the best image quality. The use of an EOL standard is also a prerequisite to any examination with the EOL, in order to determine the significance of the result (images produced are not the result of an improper adjustment).

Different types of comparison conducted with EOL II

A) **Printing matters: presence/absence comparison and comparison of different printing processes**

In most cases presented to the public, the EOL technology was used to demonstrate the presence/absence of a specific element or reveal the presence of different printing processes. We have conducted several tests to determine the presence of residual intaglio printing (Intaglio produces a raised image) in Offset counterfeit notes (Offset creates a flat image). In illustration 2, some Intaglio marks were deciphered in what we assume to be a bleached genuine $1 United States Federal Reserve (USFR) banknote. This note was bleached and fraudulently reprinted into a $100 counterfeit USFR Note. The EOL II has clearly demonstrated important possibilities in this area.

B) **Quality evaluation in the case of two documents produced with the same printing process**

The presence/absence of printing processes has been demonstrated with the EOL II but subsequent testing had to be made in the evaluation of counterfeits bearing the same printing process that is in the genuine. Some high quality counterfeits (acid etch counterfeits) were compared with intaglio genuine notes using EOL II. The analysis revealed that EOL II had a limited success at this stage of development in revealing significant differences. This limited success was caused by limitations in the enlargement capacities of the scanned image and the inability of EOL II to compare minute surface details. The EOL II could not provide a macroscopic image magnification quality. To match a forensic level quality similar to those commonly produced by our instruments (such as with the Video Spectral Comparator or with a photo microscope) the EOL technology must improve its ability of scanning small zones of evaluation, about the size of ONE typewritten character.

C) Altered documents

Several tests were also conducted in the area of alteration of travel documents, mainly in cases of mechanical erasures and handwriting indentations. Illustration 3 provides a case of a dry seal (hand made) done in a photo substitution in a United States passport. Despite the fact that the enlargements obtained from EOL were sufficient to reveal problems, greater magnification is required to reveal significant differences when comparison with a genuine mechanical dry seal (both letters "A" and "T" of attached could be compared but a higher magnification is essential to conduct a forensic comparison).

In illustration 4 taken from the same passport, the digit "5" of 1953 was probably "1963" (mechanical erasure of a digit "6"). Again the EOL II has provided limited capabilities in enlarging the erased area in order to illustrate fibre disturbance. We believe that the actual limitation of EOL is not the result of the technology itself but more the consequence of the use of scanning components designed for office use applications and not fully adapted to EOL II (insufficient scanner quality and limited software).

FUTURE APPLICATIONS OF THE EDGE OF LIGHT TECHNOLOGY IN FORENSICS

We have not evaluated the Edge of light technology by calculating the number of positive results that this instrument has provided us through six months of evaluation. We have asked ourselves if the EOL technology could provide information that is not available through the VSC or the ESDA.

1. In our opinion, the EOL provides a new technique of evaluations in forensics. At this stage of development, we think that the EOL would provide limited complementary results to information extracted from a VSC or an ESDA.

2. The EOL technology would provide unique results that cannot be obtained with a VSC or an ESDA if further developments were made to better adapt EOL technology to forensic applications.

SUGGESTED DEVELOPMENTS

1. Better scanning resolution

The actual resolution of EOL II is inferior in quality renditions to other apparatus such as VSC or photo-microscope. Enlargement setting should be targeted to obtain a full scanning zone of the size of ONE typewritten character.

2. **Automatic compensation for slit angle and height adjustment (without a readjustment)**

A compensation mechanism should be included to obtain the same slit angle at a different height. In EOL II, a new setting had to be done with the "standard settings" each time the height was changed.

3. **"Daisy wheel scanning" conducting automatically a series of images capture**

It was not possible with the EOL to determine the perfect setting for a particular type of examination or alteration. A mechanical erasure could be deciphered at a certain angle and height in one case and be different in another mechanical erasure case. The pre-adjustment of 6 or 8 settings performed automatically would greatly improve the capacity of EOL. The examiner could perform other duties while the images are produced. A more extensive examination with the best specific setting could be done by the examiner.

4. **VSC capabilities combined to EOL**

In the CPRC Technical Memorandum in Figure 5 an EOL scan of a fingerprint was recorded. A fluorescence effect may have been recorded in such cases. Such effects are similar to those produced by the VSC and extensively used in forensic examination.

Instead of the usual light source enclosed in the apparatus, a combination of the EOL with a fibre optic cable adapted to a Luma-light source could bring new possibilities. Further to this controlled light source, the possibility of a rotating wheel of different spectrum of red filters would increase the EOL to a "VSC status". The VSC is the best used instrument in forensic examination of documents. The VSC is a closed TV circuit system emitting a blue-green light source of 480-580 NM and capturing an image under different red filters, varying from 600 to 850 NM. The VSC does not provide the capabilities of a "map surface reading".

5. **Values recorded on the screen**

Forensic examination requires the registering of all parameters in order to have the capacity of redoing a case under the same conditions. For the EOL, such recording is critical since the image quality is dependent on slit angle and height measurement. All these values should be recordable at the same time images are saved. This would insure that all significant adjustments would be present to redo an examination.

CONCLUSION

EOL is a promising instrument that offers a new forensic examination technique. Results produced with the EOL are not obtainable with the ESDA machine or with the Video Spectral Comparator (VSC). At this actual stage of development, the EOL is not yet capable of producing significant complementary information in forensic examination. But the EOL technology offers interesting forensic possibilities and further developments should be considered. The main area of development of the EOL technology for forensics should be in the area of obtaining a better scanning resolution, performing automatic capturing, combining VSC illuminations with EOL and using a measurement log recording system automatically saving the values with the image capturing. This would put the EOL technology at the status of a leading edge forensic apparatus.

List of Illustrations - RCMP report

ILLUSTRATION I: TEST ON A FICTICIOUS BANKNOTE

INTAGLIO

OFFSET

EOL II

INTAGLIO

OFFSET

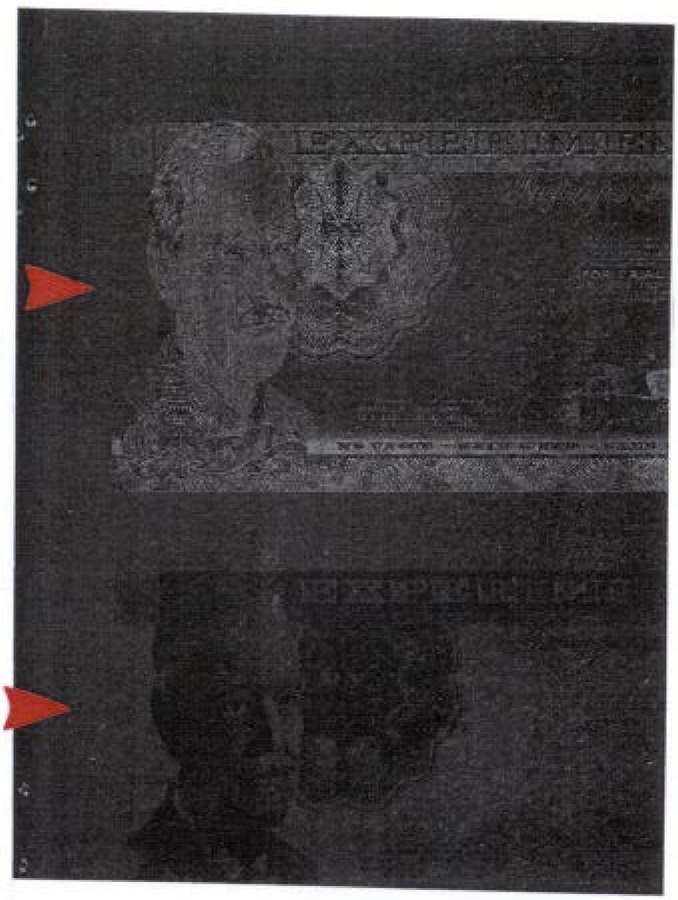


ILLUSTRATION 2: INTAGLIO MARKS ON A BLEACHED NOTE

EOL II

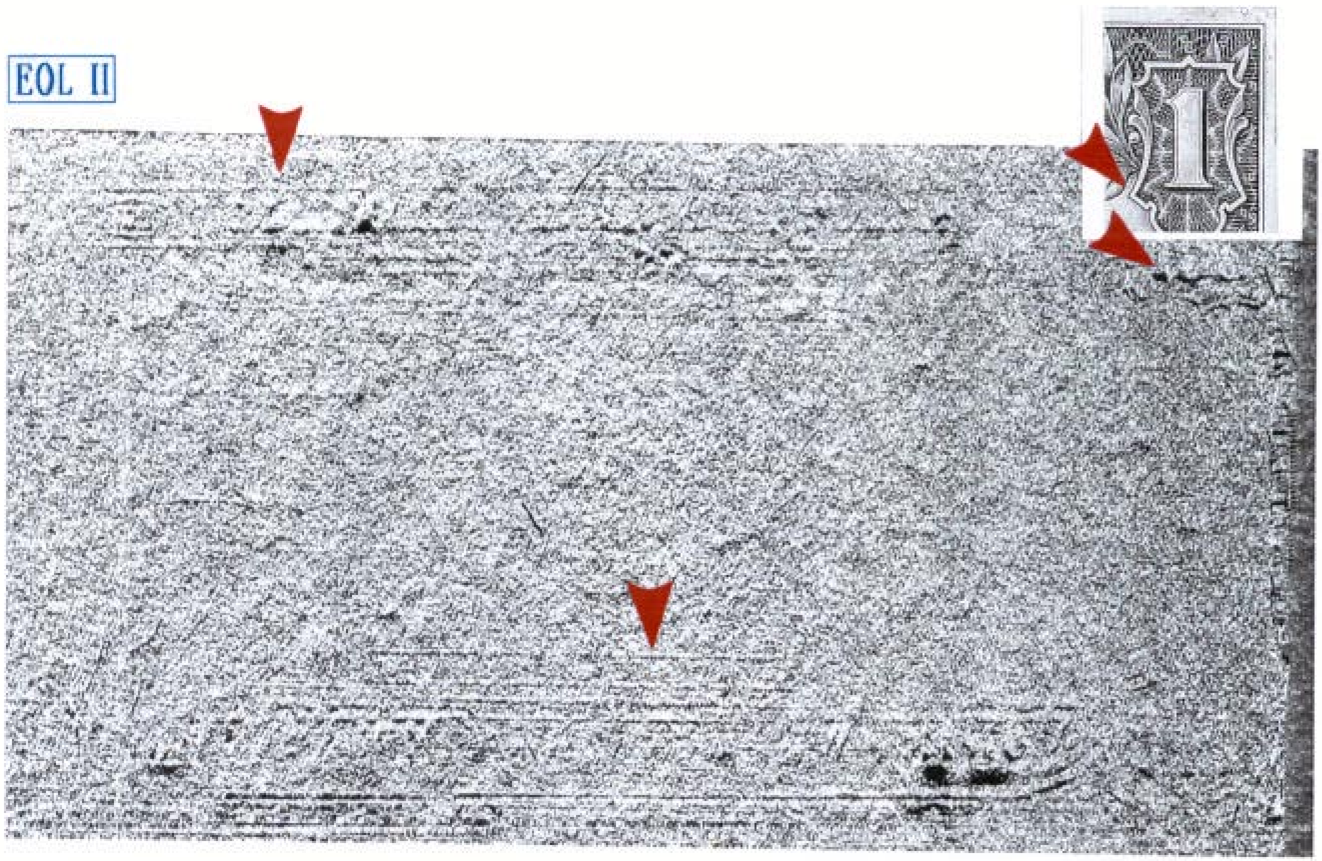
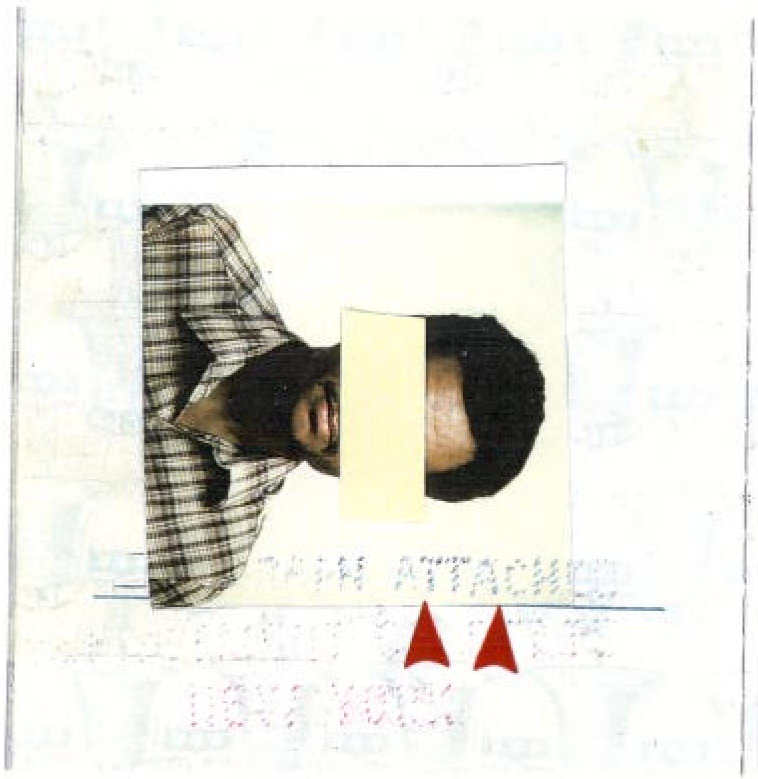
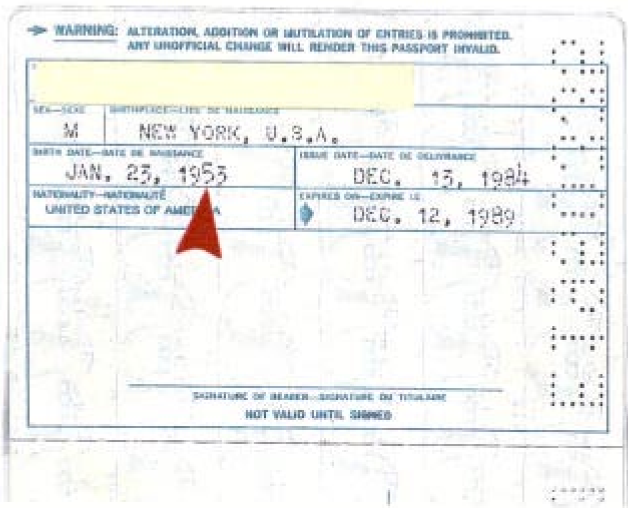


ILLUSTRATION 3: PHOTO SUBSTITUTION & HAND MADE DRY SEALS



EOL II

ILLUSTRATION 4: MECHANICAL ERASURE (1953)



EOL II

ILLUSTRATION 5: FROM CPRC REPORT 1995-06, FIGURE 5

FIGURE 5. EOL SCAN OF FINGERPRINT ON GLOSSY BOOK COVER

FIGURE 6. EOL SCAN OF FINGERPRINT ON GLASS SHEET

(Note: Fingerprints are untreated)

" EDGE OF LIGHT - OPERATIONAL ASSESSMENT" - REVENUE CANADA

INTRODUCTION

Document examiners routinely examine documents for indented or embossed material. Oblique lighting and a microscope is one method used for these types of examinations. The ESDA (Electra-Static Detection Apparatus) is another method usually employed in the examination of indentations.

The following report provides an evaluation of the Edge of Light (EOL)[1] technology with respect to decipherment of indentations and examination of embossment defects on questioned documents and other types of potential exhibit material. The EOL apparatus was developed by the Institute for Aerospace Research, Structures, and Materials Laboratory, National Research Council Canada. The flat-bed scanner phase II prototype version was set-up at our laboratory. An illustration' of the apparatus set-up is seen in Figure A.

PROCEDURE

During the time period of evaluation, many different types of exhibits and documents were examined. See Table 1 for a list of the types of materials examined.

In each case the following basic steps were taken:

1. Initial settings were noted. A) the height of the scan head above the exhibit (zeroed first, then adjusted from the zero setting at the top of the micrometer attached to the scanner), B) the values for F1=Optical Slit Adjustment(not changed), F2=EOL edge(mirror adjustment with range of 0 to 100 units), F3=Focus (with a range of 0 to 150 units). C) orientation of the exhibit to the scan head (generally parallel to the scan head, with the scan coming from the left to right across the document/exhibit). D) Vacuum on or off, with or without plastic covering over exhibit.

2. All scans were done at 600dpi resolution. This was set in HP Scanjet II under Custom print path.

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1 TM 2 l-95/7 Micro Inspection Technology - EOL - Edge of Light Optical Enhancement Technology, Technical Memorandum April 1997, by A. Marincak, R. W. Gould, J. P. Komorowski, Institute for Aerospace Research, Structures, Materials, and Propulsion Laboratory, National Research Council Canada.

2 Ibid, Addendum

3. Images obtained were usually unenhanced but, when required, the contrast and/or brightness was adjusted through Picture Publisher (the software package on the computer).

4. Images were saved as TIFF files so that no loss of detail occurred (as is the case in some image formats such as JPEG).

RESULTS

Due to the amount of raw data generated in the evaluation of the materials listed in Table 1, only a sampling of results are illustrated here. The EOL parameters for each of the illustrations are described within the Figures where they appear.

Indentations

Four types of indentation cases/tests are reported. The first case is a prepared test sample of indented handwriting, the second, an actual exhibit where questioned indentations and erased writings were examined, the third, an examination of indentations that were covered with scotch tape on a shredded document, and the fourth, fuser roller impressions in the surface of toner on a laser printed test page.

Case #1: Figure 1 illustrates the prepared test sample of handwritten entries and the page that was directly below it when it was written. The upper image (page 1) shows what was originally written with various pressures (ie. a = heavy pressure, b = light pressure, c = moderate pressure), while the lower image (page 2) is the page that was present below the page with the original writing on it. Results from the EOL of the indented impressions on page 2 are seen in Figure 2. Figure 2 a. illustrates both areas of light and moderate writing pressures. Figure 2 b. illustrates just the light writing pressure. The heavy pressure was fully resolved by the EOL and was not illustrated here. The greatest amount of handwriting stroke detail between b and c was seen in the moderate pressure indentations (area c) of page 2. The weaker indented impressions of (area b) were not resolved well. Figure 3 illustrates an ESDA of page 2. Conditions for the ESDA are listed in Figure 3. The ESDA resolved all indentations very well.

Case #2: Figure 4 illustrates questioned exhibit Q5(3), a sheet of lined graph paper which contained handwriting entries. Please note that any names were obliterated on this copy of Q5(3). Two questioned areas were examined on this exhibit. The first was located at the mid-right side of the page near the word “Writing” in "__________ Replys in Writing”, this was where an erasure had occurred. The second was at the top left side of the page around the beginning of the second paragraph. This was where indented writing occurred. See Figure 5 for the ESDA of exhibit Q5(3). Multiple trials were done to try and resolve the erased written area. None were successful, as can be seen in the lower image of Figure 5. The upper image of Figure 5, illustrates the indented impressions at the top of the exhibit. The resolution of detail is much better there. Figure 6 a. illustrates the results of the EOL technique in the questioned erased area, and Figure 6 b. illustrates the questioned indented area results. The EOL image is very faint in Figure 6 b., only the word "Aug" was partially resolved. The EOL image is better of the erased words "obtaining the new Ford ca__y" in Figure 6 a.

Case #3: A shredded document was examined for indentations on the paper but covered by scotch tape. This type of document would not be well suited to ESDA for indentation examination since it was very rippled on the surface and humidity would not help due to the interference from the tape. Figure 7 is a copy of the questioned bottom portion of exhibit D62. Figure 8 is a comparison of EOL results of the area bounded by the "S" of Phones and the "S" of Shanjhai in line 1 of Figure 7 and the "4" of 24 and "P" of line 3 on exhibit D62, that was covered with scotch tape, with and without using the EOL plastic covering. This case was illustrated to show that the amount of reflection increased with the plastic covering plus the tape to an extent that it caused interference. The loss of resolution in the images of Figure 8 is due to the reduction in size and detail necessary to be able to print them together in the same image. The arrows indicate the indented text.

Case #4: A laser printer test sheet was examined for fuser roller impressions in the toner surface. It was hoped that the EOL would be able to pick up the pattern in both the solid black and text portions of the test print, thus enabling the EOL to be used as a quick scan technique for fuser roller defects in laser printed documents. Figure 9 illustrates a scanned image and microphotographs of certain sections of the laser printer test sheet. The test sheet had an area of solid black at the top of the page followed by text. Figure 10 a. illustrates the EOL image of the fuser roller impression in the extended dark portion at the top of the page. The EOL did not discriminate the fuser roller impressions in the printed text itself, see Figure 10 b.

Embossments

Three case examples of embossed details were examined. The first involved an examination of printing characteristics on a label that was attached to a cigar box and on a standard unattached label. The second involved an examination of print ridge detail from a treated fingerprint on a magazine page. The third involved the examination of a questioned embossed area on the collar of a black jacket.

Case #5: Figure 11 illustrates an EOL image (Figure 11 a) and a digitally enhanced image (Figure llb) of a questioned embossed Habanos label which was adhered to a wooden cigar box that was 27.4 cm long x 14.1 cm wide x 4.8 cm high. Figure 12 illustrates an EOL image (Figure 12a) and a digitally enhanced image (Figure 12b) of a standard embossed Habanos label which was not adhered to a box. The amount of damage to the label influences the appearance of the embossed detail. This type of exhibit would not be able to be examined for embossment detail with the ESDA due to its odd shape and the requirement for enhancement of the image by the computer.

Case #6: Figure 13 is an illustration of a comparison between an EOL image of a treated fingerprint on a magazine page and a 1000 dpi scanned image of the same print. The scanned image was done on an AGFA duo-scan scanner set at 1000 dpi resolution. Figure 13 (which contains both images) was printed on a HP laser-jet 4V at 400 dpi. No plastic was used over the magazine page as it had its own reflectance and due to the possibility that covering it might have removed the treated embossment. The treated fingerprint ridge detail was not totally clear on the page, it was hoped that enhancement of the ridge detail may have been possible. Both images were similar in clarity prior to being printed for their illustration in this report.

Case #7: Figure 14 illustrates two images taken with the EOL of a questioned embossed area on a cutout of the collar of a jacket. The collar was cut off of the jacket so that it would lie as flat as possible. Figure 15 is an ESDA of the same questioned embossment on the fabric collar cutout. One can see that neither the EOL or the ESDA was able to resolve the image pattern.

DISCUSSION

In summary, from the preceding illustrations one can see that the EOL worked well in providing a non-destructive method to examine surface detail information on erased indentations on paper (Figure 6a), moderate pressure indentations on paper (Figure 2a), embossed (raised) images on labels after digital enhancement (Figure 11 b), and on odd exhibit materials (ie. wooden box label, paper covered with tape, glossy magazine page with treated fingerprint - Figures 11 b, 8b and 13 respectively). The EOL did not perform well on weak indentations in paper and on fuser roller impressions in toner text (ie. Figures 6b and 10b). Both these types of indentations require increased resolution. It is also possible that alternate orientation to the scan-head with the averaging of multiple images and/or increased resolution could have resolved the finer indentation details. Due to time limitations, this could not be explored for this report.

Most of the case materials examined above were actually from casework in this laboratory and thus the exhibits had to be returned to the investigators. The time available was limited to examining various possible combinations of reflective covering materials and orientations of exhibits to the scan-head. The resolution of the scanner only went to 600dpi, and the scan-head mirror could only be adjusted to a certain degree before lines were introduced into the image from mirror defects. Also, with respect to the EOL prototype performance there was a focus problem affecting the clarity/resolution of fine details in some of the images.

Having standards to setup the apparatus for the different types of exhibit material examined would have been an asset, but, due to the nature of document exhibits too much variation exists and no standard conditions can be utilized.

Comparison of the results of the EOL and the ESDA (where applicable) disclosed that the EOL performed better in resolving erased writing and in examining surface indentations non-destructively on odd shaped and thick exhibits, and on fragile exhibits which could not be covered with plastic (ie. the fingerprint exhibit). The ESDA performed better on weak indentations in paper. Even so, it is felt that with certain adjustments the EOL apparatus could become a viable apparatus for the document examiner since it is not necessary to humidify the exhibits or use toner to develop the image. The images are captured in the computer and they can be enlarged and enhanced during their development, something the ESDA cannot do.

CONCLUSIONS & RECOMMENDATIONS

The EOL is a viable alternative to the ESDA especially in cases where erased writing, embossments and odd type of exhibit materials exist. Keeping in mind that the EOL Phase II is just a prototype, there are a number of adjustments that could be made to enhance its performance in these and other areas. Listed below are some adjustments which should be taken into consideration:

a) increase scanner resolution options to go up to and include 1000 to 1500 dpi.

b) increase size of vacuum bed area so that an 8” x 11” page can be oriented vertically or horizontally and not be creased by the cover edges.

c) add an automated step through function for height, focus, and mirror adjustment as an option/alternative to the manual (time consuming) triple adjustments. The manual adjustments should still be kept to get the best image once a reasonable range is found automatically.

d) add an ability to use variable light sources (ie. UV, IR) this would expand the range of exhibits which could be investigated.

e) use another software package for enhancing the EOL images (ie. one like Adobe Photoshop 3.0 or 4.0).

f) ensure printers like HP Laserjet 4V or Kodak XLS 8600 PS are compatible with the package.

g) upgrade the computer to one which can process and store large images quickly, especially colour and 1000 dpi images (ie. the latest Pentium with a large memory - at least 128 Megabytes RAM and a double hard drive).

Due to limited time available, other areas of interest (ie. intersection of strokes), and further study of fuser roller defects and weak indentations in various paper stocks could not be done. Further study is required in these areas.

At present it is felt that the EOL with some adjustments could be used as a complementary technique to the ESDA in cases outlined previously. Future research may show it has greater capabilities and it may have the potential to replace the ESDA and assist in providing a quick screen for fuser roller defect presence/absence in whole documents.

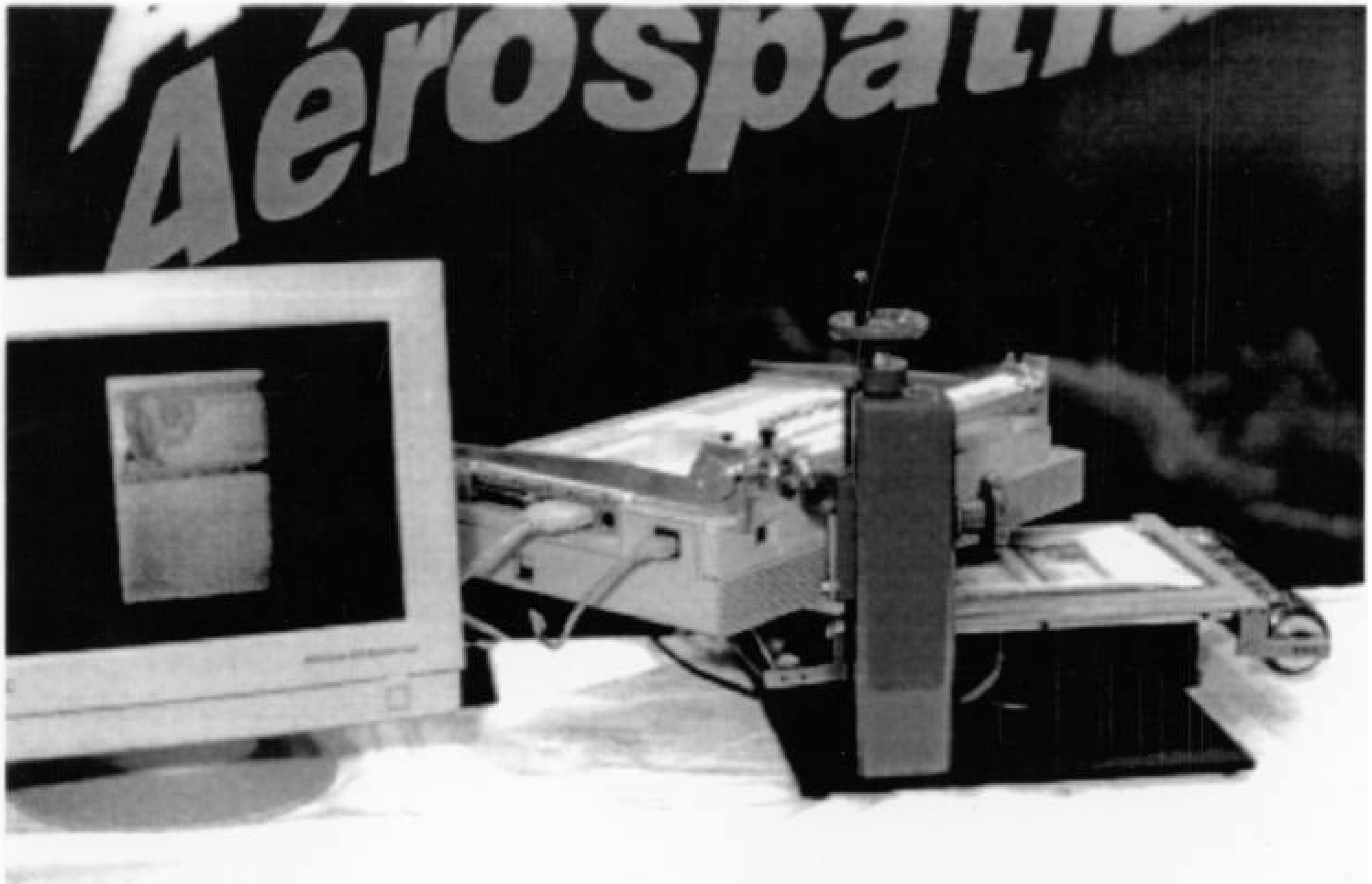
TABLE 1

List of Examinations Performed with EOL Apparatus

1. Examination of prepared indentations varied pressure on a sheet of lined notepad paper.
2. Examination of a traced signature on a photocopied document for indentations (Case file 123143).
3. Examination of a page of lined notepad paper for indentations (Case file 124352).
4. Examination of a page of lined notepad paper with erased handwritten material (Case file 124352).
5. Examination of embossment of label on collar of jacket (Case file 124789).
6. Examination of treated fingerprint on magazine paper.
7. Examination of fuser roller patterns in toner on a laser printer test sheet.
8. Examination for fuser roller indentations on a letter (Case file 124172).
9. Examination of indentations on shredded/taped documents (Case file 124733).
10. Examination of questioned embossments on a printed label on a cigar box and on a label from a standard roll of labels (Case file 124172).
11. Examination of indentations on a cardboard index card .

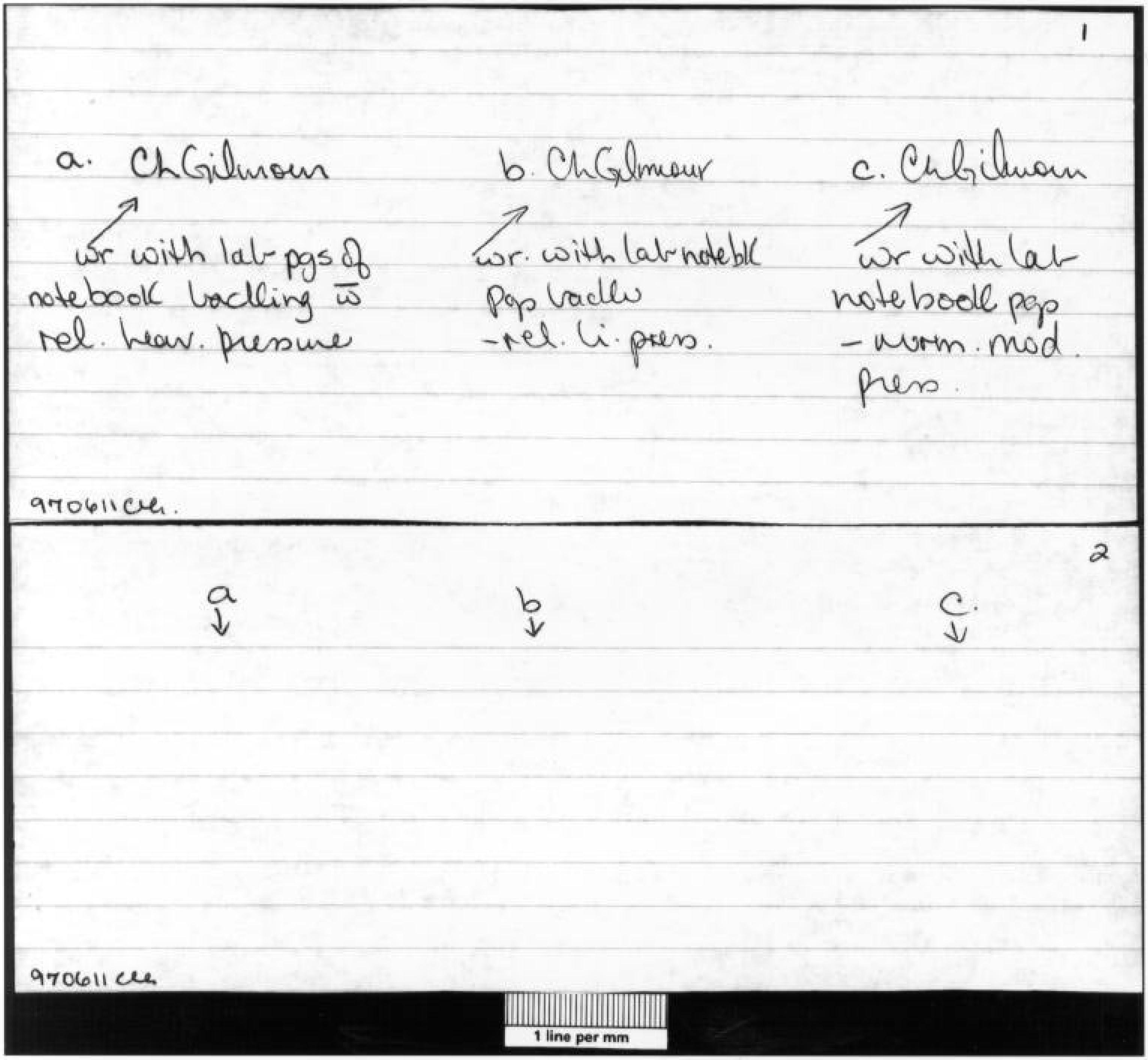
List of Figures - Revenue Canada report

Figure A



EOL Flatbed Scanner on adjustable height mast over Solid Film Highlighter Vacuum Table

Figure 1



1

a. ChGilmour
wr with lab pgs of notebook backing w̄ rel. heav. pressure

b. ChGilmour
wr. with lab notebk pgs backg -rel. li. pres.

c. ChGilmour
wr with lab notebook pgs - norm. mod. pres.

970611 CH.

2

a ↓

b ↓

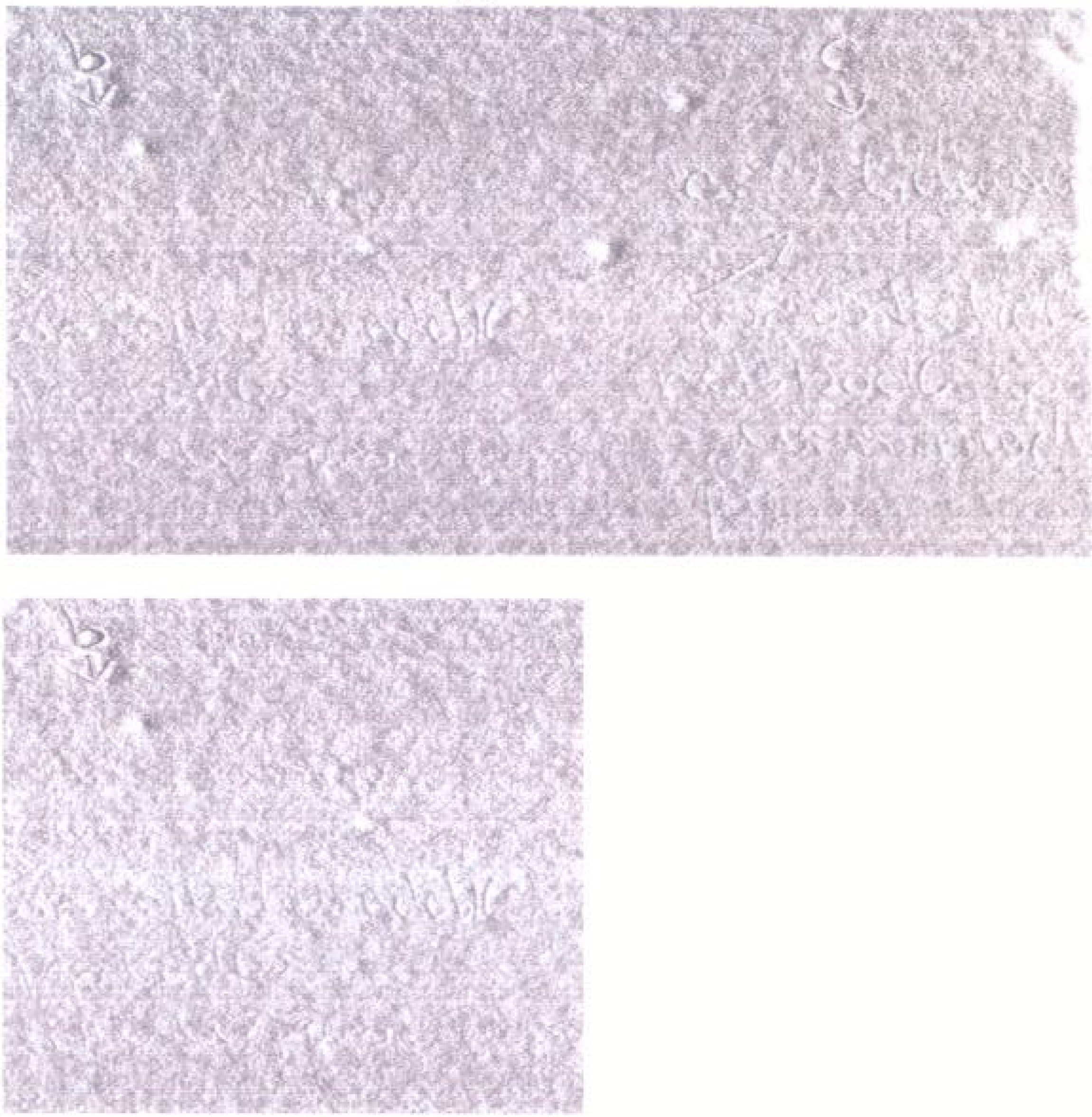
c. ↓

970611 CH

Figure 2

a.

b.

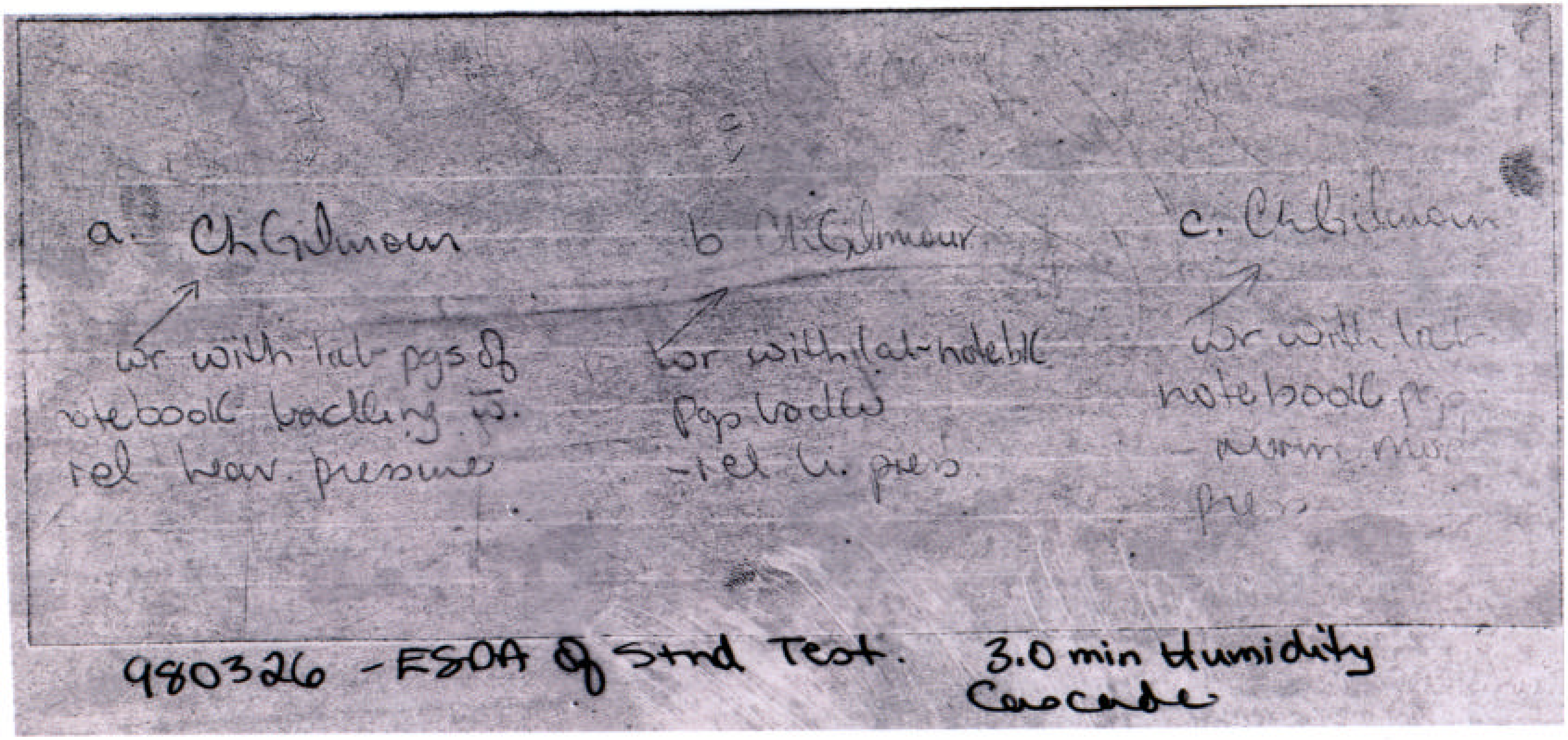


EOL Settings

a. F1 = 69, F2= 24, F3 = 130, Distance below zero = 48.00 mm

b. F1 = 69, F2 = 24, F3 = 130, Distance below zero = 48.05 mm

Figure 3



ESDA of Standard Indentation Test Page 2

Figure 4

Letter from   from
dated Mar 28th

It was nice (Etc.) to meet you with
&   in Guelph when we discovered
that the mould you developed will
work on our Canadian Made 450T
press (350,000 CAN) rather than our imported 700T from
the USA (450,000) — Should make
your export sales - better opportunity (re) cost
of hydro for operations. The demonstration
re mould charges & actual injection cost

(#Hot)

Replys in writing

TKS & yes the demo resulted in
Ford accepting the   Technology
(One of our dedicated suppliers) got Ford
to specify — Spinoff effect

Original Pencil Written Document with Names Obliterated

(3) 970910aa 124352

1 line per mm

Figure 5

Illustration of the Indentations at the top of the page done with ESDA

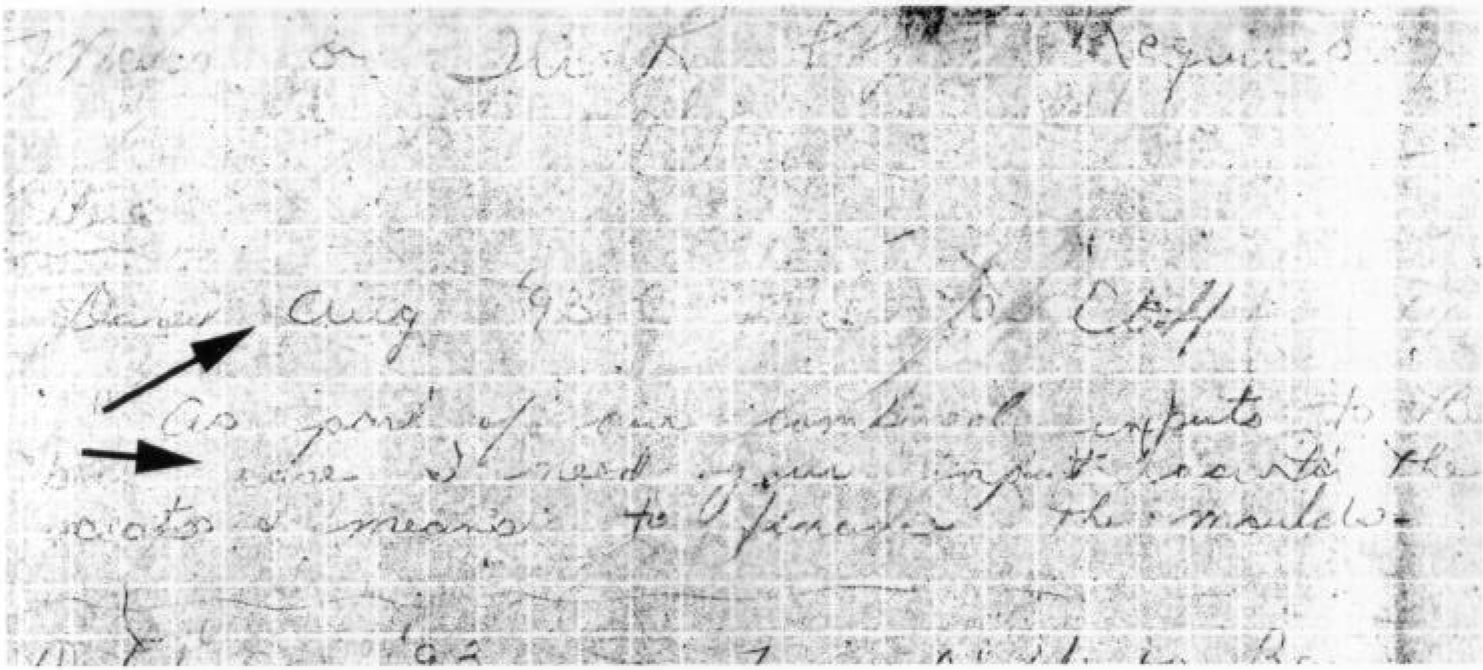


Illustration of the Indentations at the mid-right side of the page done with ESDA

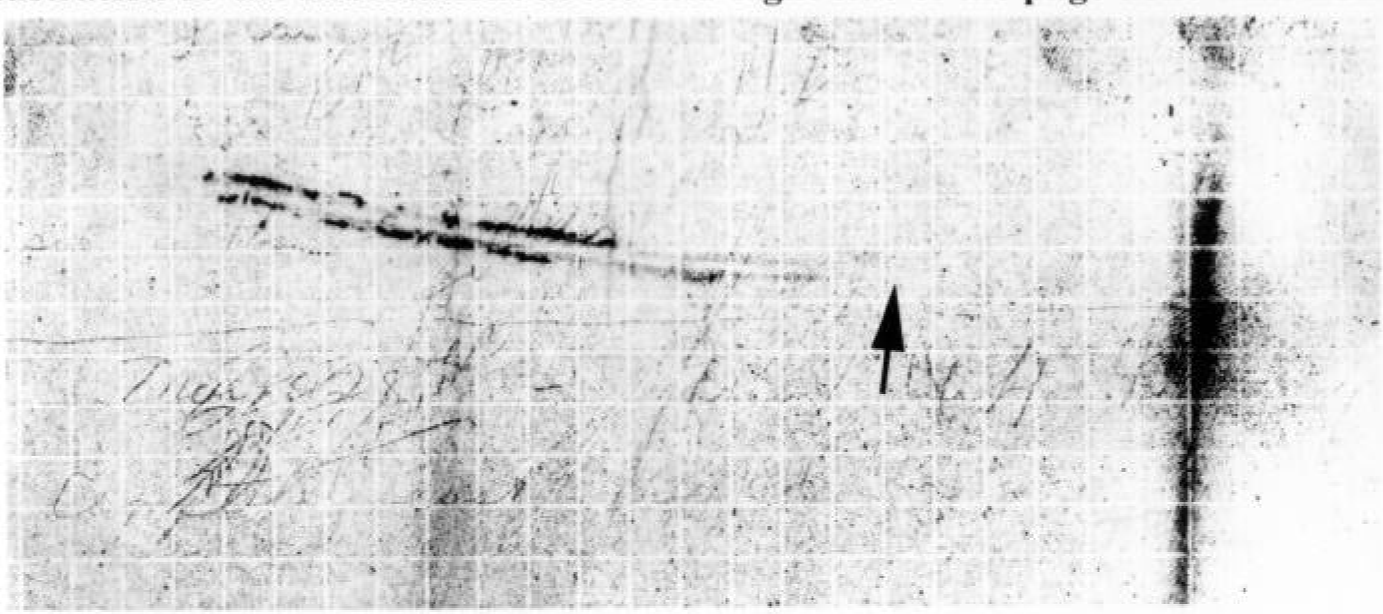
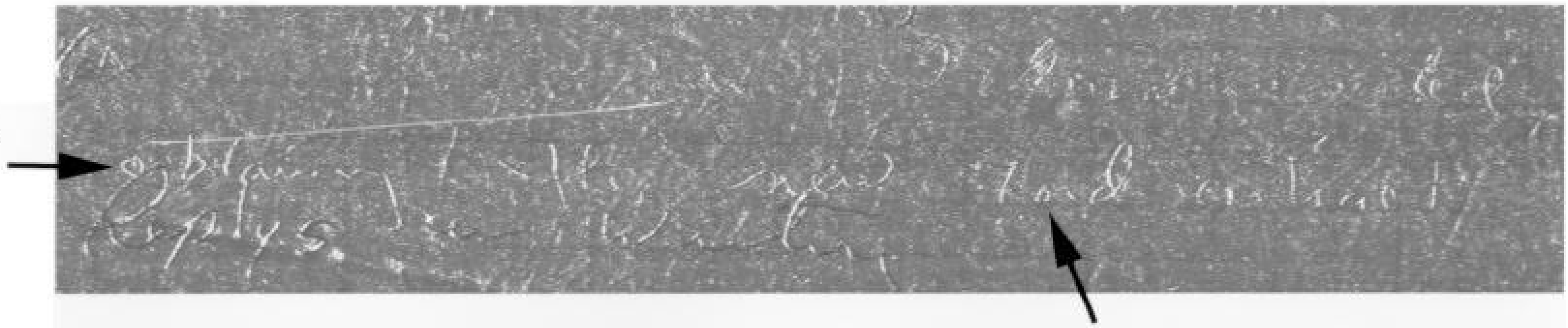


Figure 6

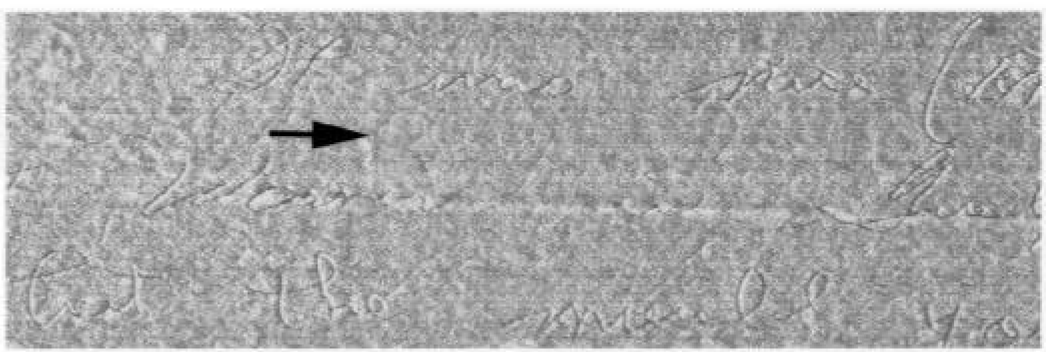
a.



EOL Erased Writing Settings

F1 = 69, F2 = 48, F3 = 135, Distance below zero = 48.68 mm

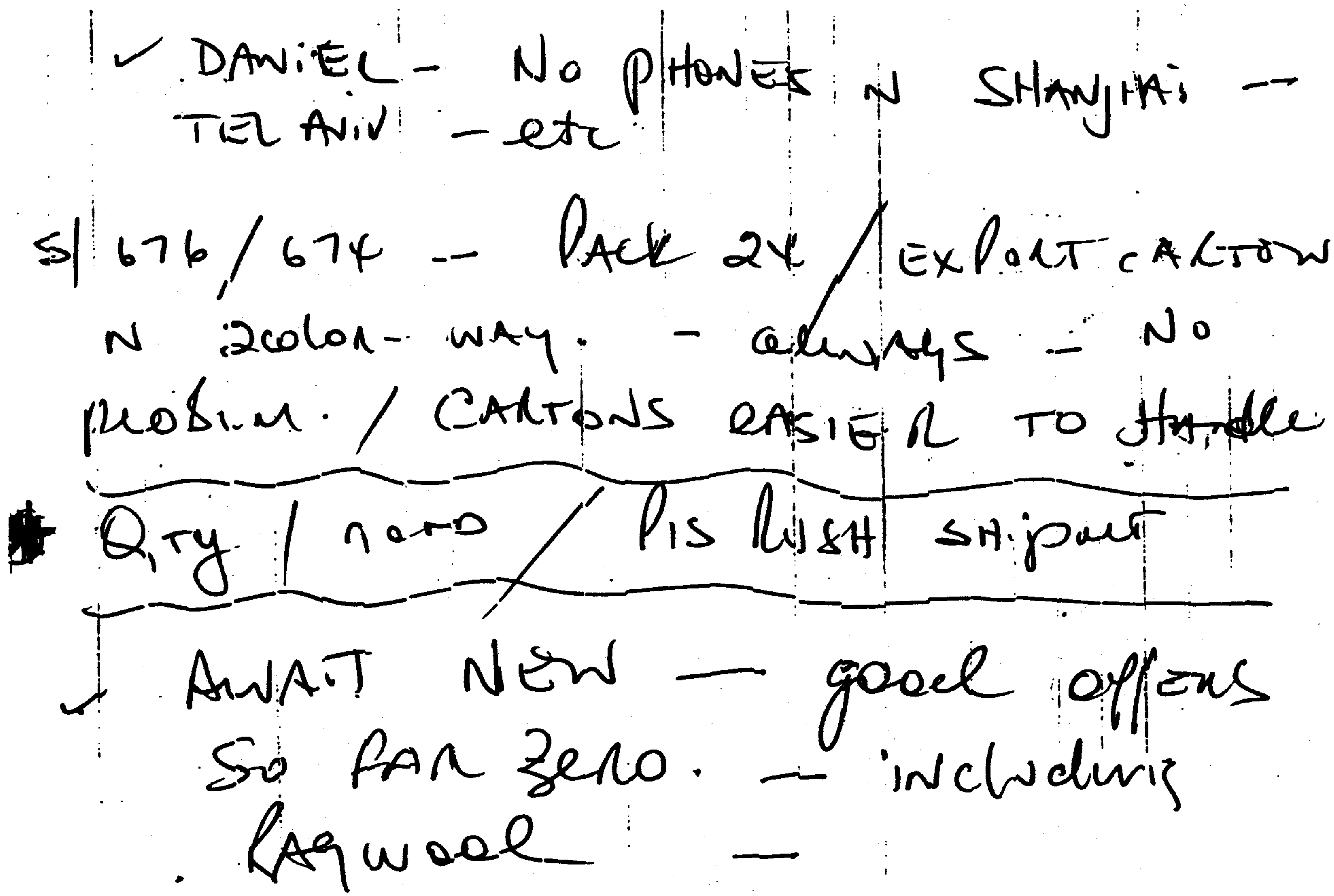
b.



EOL Indented Writing

F1 = 69, F2 = 19, F3 = 135, Distance below zero = 48.40 mm

Figure 7



✓ DANIEL – NO PHONES N SHANGHAI –
TEL AVIV – etc

S/ 676 / 674 – PACK 24 / EXPORT CARTON
N 2COLOR- WAY. – ALWAYS – NO
PROBLEM. / CARTONS EASIER TO Handle

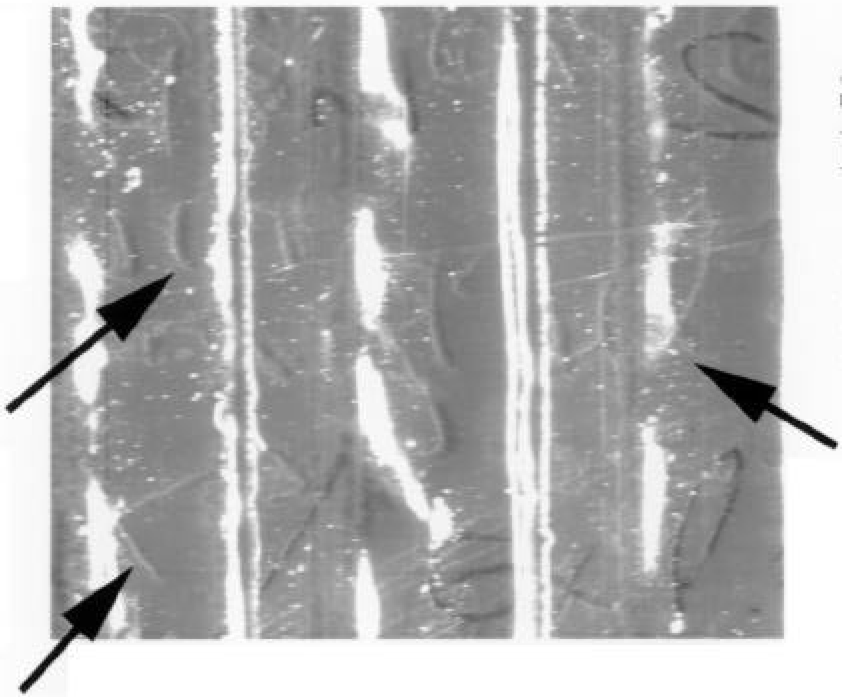
Q,TY / norm / Pls RUSH shipment

✓ ANAT NEW – good offers
SO FAR ZERO. – including
RAGWOOL –

Bottom of shredded exhibit D62 which has been taped together

Figure 8

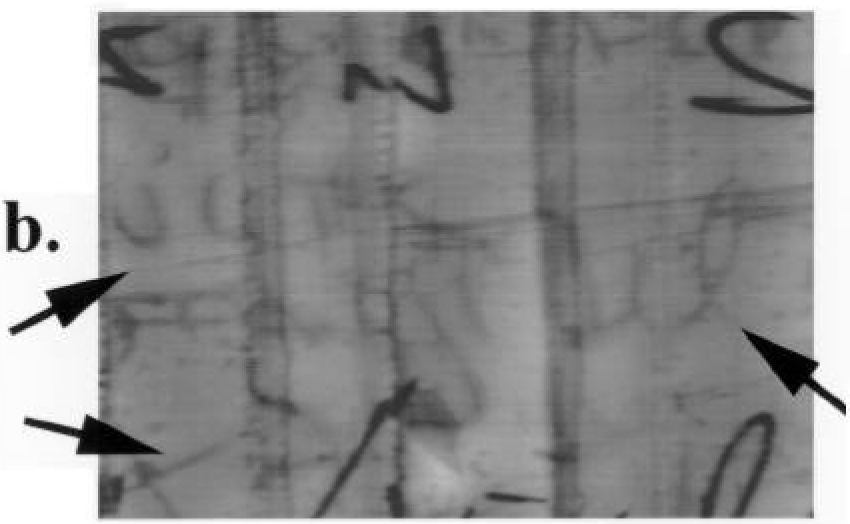
a.



Shredded Document with Plastic Over Taped Surface

F1 = 69, F2 = 96, F3 = 135
Distance below zero = 51.0 mm

b.

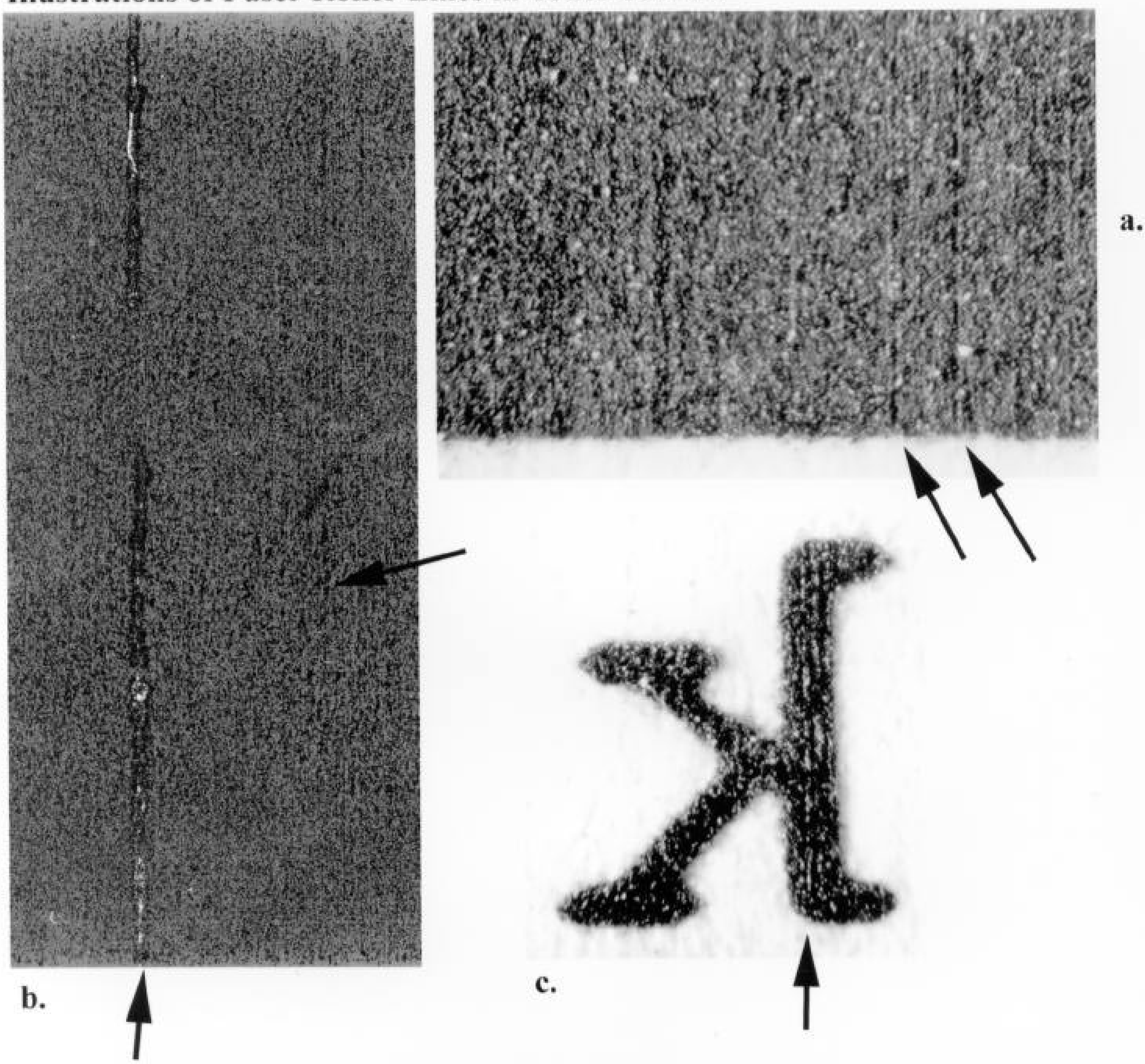


Shredded Document Without Plastic over Taped Surface

F1 = 69, F2 = 2, F3 = 135
Distance below zero = 51.0 mm

Figure 9

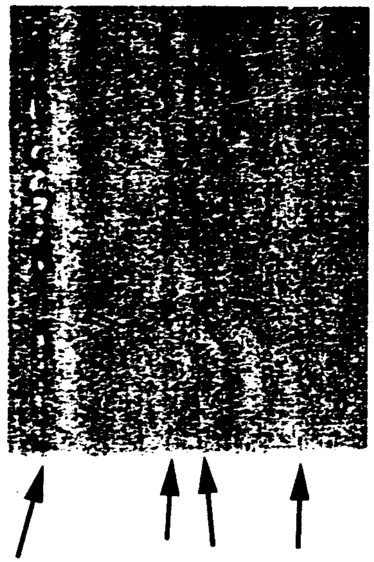
Illustrations of Fuser Roller Lines in Toner Surface



Images a. and c. were taken with a Polariod MiroCam at 1.6x magnification
Image b. was taken with the AGFA Duoscan Scanner at 600 dpi

Figure 10

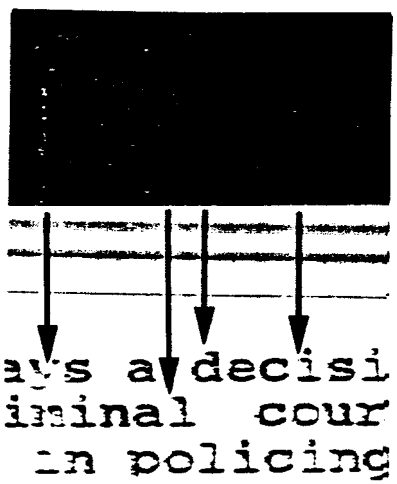
a.



EOL of Fuser Roller Marks on Laser Printer Test Sheet

Fl = 69, F2 = 20, F3 = 135
Distance below zero = 50.64 mm

b.



EOL of Fuser Roller Marks on Laser Printer Test Sheet in Text

F1 = 69, F2 =20, F3 = 130
Distance below zero = 50.55 mm

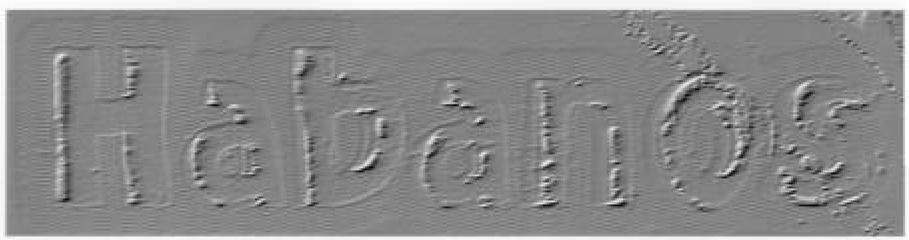
Figure 11

a.

EOL Image of Questioned Habanos Label on Cigar Box

F1 = 69, F2 = 30, F3 = 135
Distance below zero = 2.61 mm

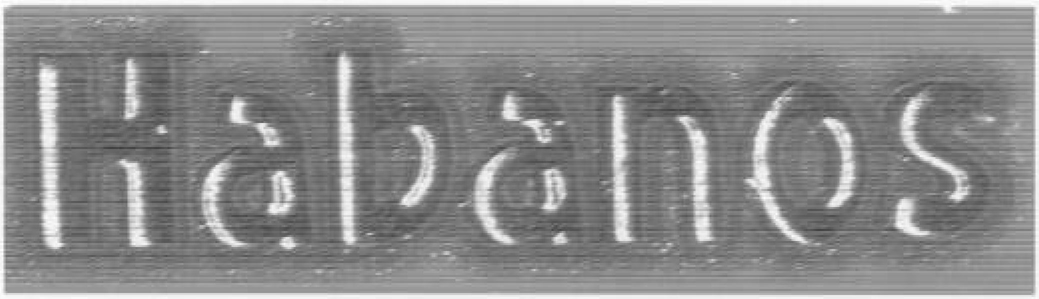
b.



EOL Image with Embossed Effect Tool used to Illustrate Raised Edges

Figure 12

a.



EOL of Standard Label on Roll

F1 = 69, F2 = 48, F3 = 135
Distance below zero = 48.96 mm

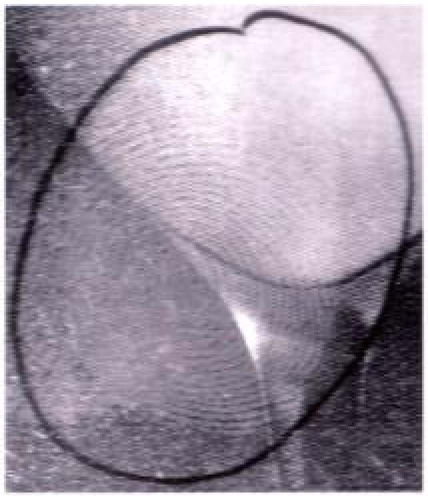
b.

EOL Image with Embossed Effect Tool used to Illustrate Raised Edges

Figure 13

Treated Magazine Fingerprint

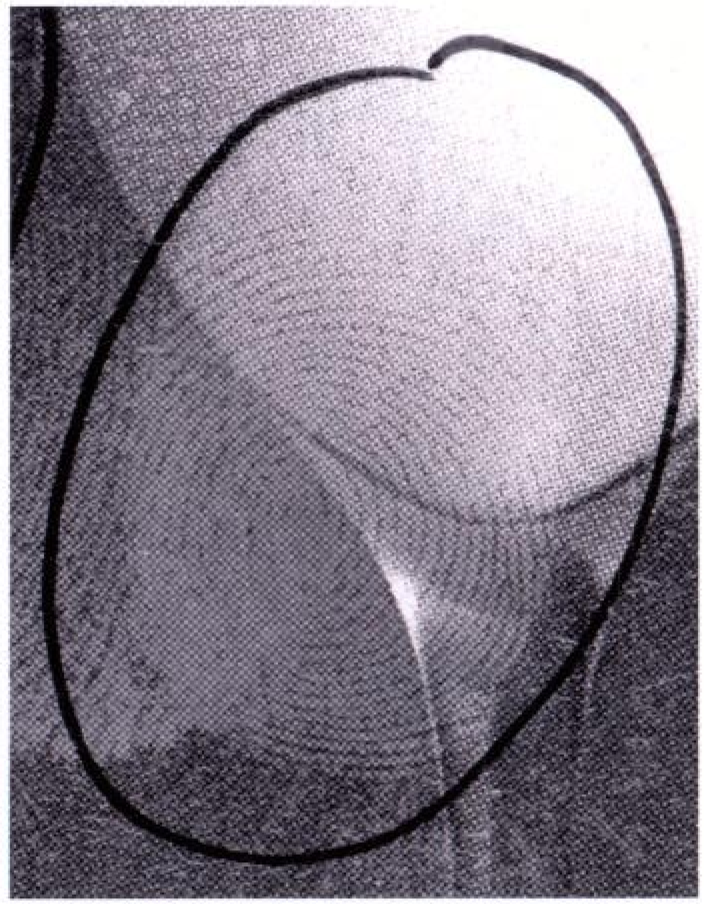
EOL



Scanned at 600 dpi

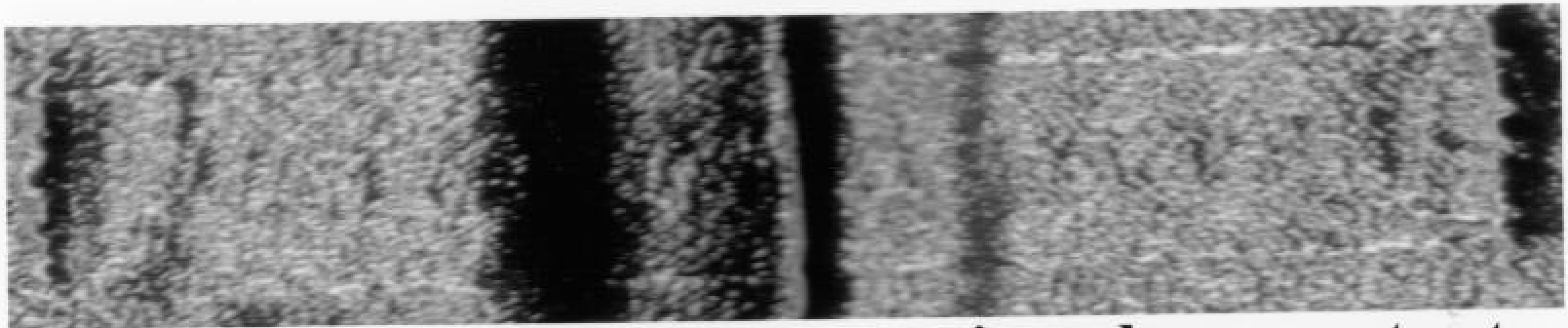
F1 = 69, F2 = 5, F3 = 132
Distance below zero = 50.48 mm
No vacuum and No Plastic Cover

AGFA SCANNER



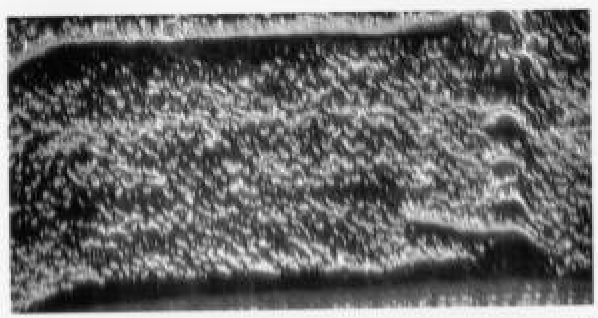
Scanned at 1000 dpi

Figure 14



Full EOL image of collar questioned area cutout

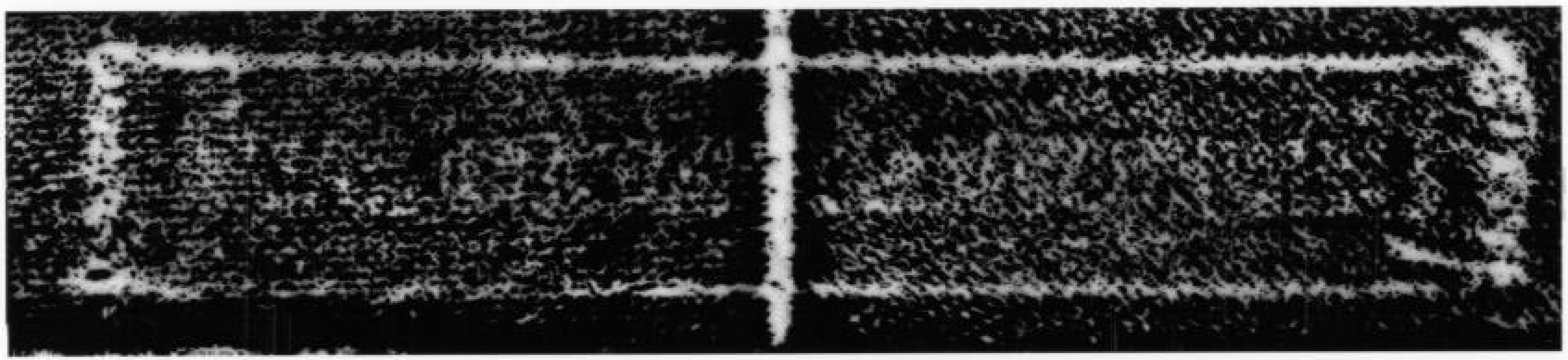
F1 = 69, F2 = 22, F3 = 130 Distance below zero = 48.26 mm



Partial EOL image of collar questioned area cutout

F1 = 69, F2 = 25, F3 = 142 Distance below zero = 49.52 mm

Figure 15



ESDA of collar questioned area cutout

Conditions: No Humidity with Cascade Method

NRC-CNRC Information - The Edge of Light™ Enhanced Optical NDI Technique IAR Fact Sheet

NRC-CNRC Information - The Edge of Light™ Enhanced Optical NDI Technique IAR Tech Sheet

NRC·CNRC
INFORMATION

IAR
Fact Sheet

The Edge Of Light™ Enhanced Optical NDI Technique

Figure 1: *The left half is an Edge of tight image of genuine (top) and counterfeit Canadian $20 bank notes. Covering the notes with aluminum foil removes any non-topographical features from* **the image.** *The right* **half** *is a normal view of the same* **notes.**

Edge of Light™ is a recently invented technology for non-destructive inspection (NDI). What makes the Edge of Light scanner unique is an ability to convert surface slope changes into light intensity variation in an image. This technology has tremendous potential in such diverse areas as forensics, detection of fatigue cracks, surface topography, and detection of "pillowing" or deformation due to corrosion in lap joints.

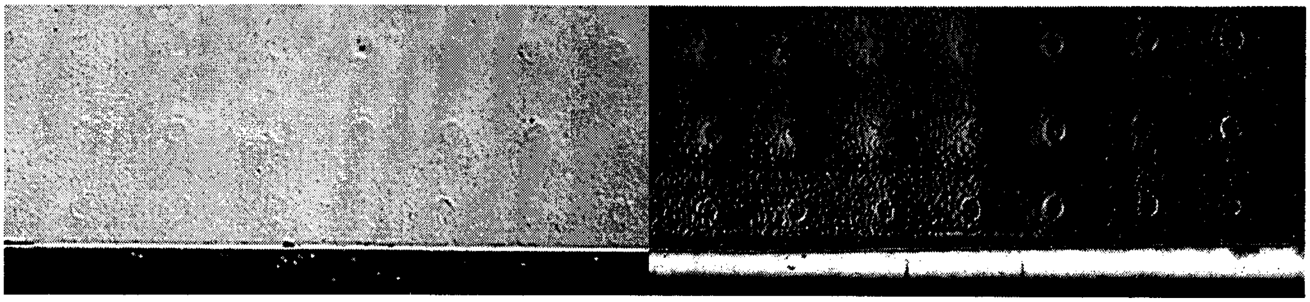
Applications

The Edge of Light technique has already been successfully used in a wide variety of applications, both in aerospace and in other, more unexpected, areas.

Aerospace

Fatigue cracks

A probability of detection (POD) study for fatigue cracks in turbine engine disk bolt holes



Figures *2 (left) Lap splice joint from a Boeing 727, as seen by the unaided eye and* (right) *Edge of Light image of the* **same** *lap splice joint. Pillowing due to corrosion is evident in most of the Edge of Light image.*

showed that Edge of Light performs better than liquid penetrant, magnetic particle, or ultrasonic inspections of the same components. Edge of Light was also significantly better than optical microscopy for this application. Edge of Light highlights surface deformations for an image quality far beyond a simple magnification.

Pillowing

Deformation due to corrosion in lap joints of commercial airliners is accompanied by a bulging ("pillowing") between rivets, due to the increased volume of the corrosion product over the original material.

Figure 2 (right) shows an Edge of Light scan of **a lap joint** with corrosion. Most of the rivets in this half of the image appear to be raised from their surroundings, with lighter than ambient brightness on the left of the rivets and darker on the right. This is an optical illusion. The area between the rivets is actually higher than the rivet level due to corrosion pillowing; the maximum slope is at the edge of the rivets.

Other Applications

Forensics

Edge of Light can also be used to study documents or works of art that may be counterfeit or altered, to analyze handwriting, and to detect credit card modification.

Surface topography

Figure 1 shows an Edge of Light image of genuine and counterfeit Canadian $20 bank notes. A sheet of aluminum foil has been conformed onto the top surface of the bills to demonstrate that the visible differences are due to surface topography and not colour. The genuine note is immediately distinct from the counterfeit in the Edge of Light scan.

How it works

An Edge of Light scanner in its simplest implementation consists of a light source and a detector held at a constant separation distance. The optical path in the Edge of Light scanner converts surface slope changes into light intensity variation. For more detail, please see our technical information sheet, IAR35E.

Opportunities

The National Research Council is working actively to develop licensing agreements and collaborative development projects to apply the technology to a variety of testing options. Because Edge of Light is so easy to use and its images so easy to interpret, it shows great promise for applications in aging aircraft NDI, as well as in forensic studies. Licensees and collaborators can count on NRC research staff having the knowledge and expertise to find the right approach to a broad range of research challenges.

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August 1999
Aussi offert en français
IAR34E

NRC·CNRC

INFORMATION

The Edge Of Light™ Enhanced Optical NDI Technique

IAR

Tech Sheet

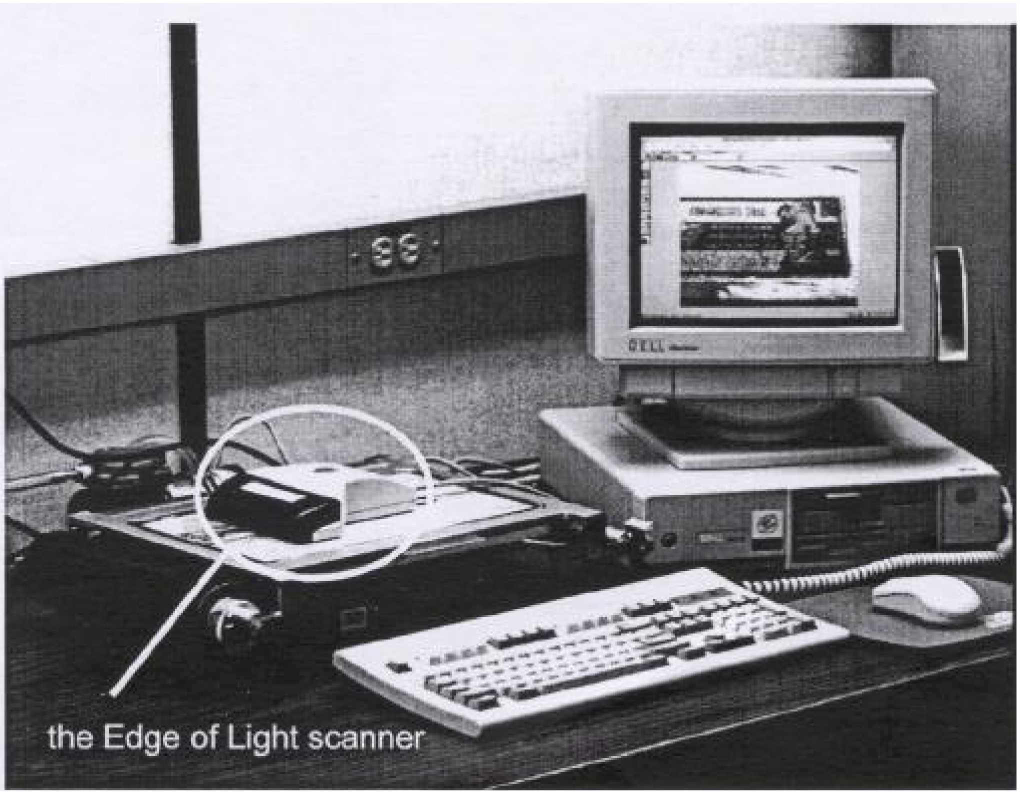


Figure 1: A complete prototype Edge *of Light inspection system, with the scanner highlighted.*

Technical information

Edge of Light™ is a recently invented technology for non-destructive inspection (NDI). What makes the Edge of Light scanner unique is an ability to convert surface slope changes into light intensity variation in an image. It shows tremendous potential in such diverse areas as forensics, detection of fatigue cracks, surface topography, and detection of "pillowing" or deformation due to corrosion in lap joints.

To learn more about the exciting applications and market potential of Edge of Light, please refer to our fact sheet, IAR34E.

How it works

The simplest implementation of an Edge of Light scanner consists of a light source and a detector held at a constant separation distance. Light passing through a slit is reflected from the inspected surface at a shallow angle and captured by the detector. The technique is relatively quick, with scanning speeds in the order of 2 to 20 linear cm per second and line widths of 10 cm or more. Edge of Light inspection results are easily interpreted, as they closely resemble the actual subject. A prototype scanner is shown in Figure 1.

National Research Council Canada
Conseil national de recherches Canada
Institute for Aerospace Research
Institut de recherche aérospatiale

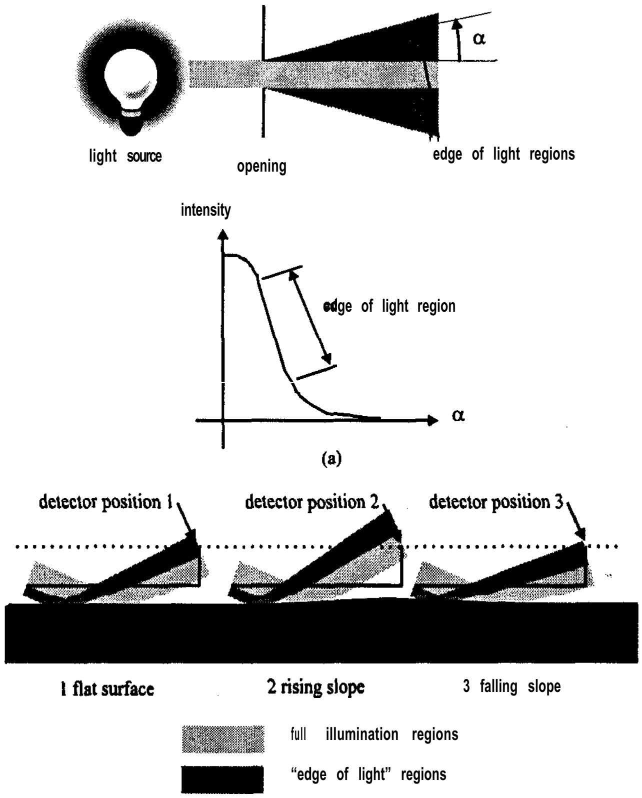


Figure *2: (a) Diffraction or "edge of light" zone (b) Slope changes in subject cause the detector to move with respect to the edge of light zone.*

The optical path in the Edge of Light scanner converts surface slope changes into light intensity variation. A light source behind a slit is used to produce a rectangular band of light on the surface of the object to be scanned. In the main zone of the band, the intensity is constant. At the edge, the intensity does not fall to zero immediately – due to diffraction effects – although it does drop off rapidly with distance, as shown in Figure 2 (a).

The detector of the Edge of Light scanner is set up to operate in the middle of this "edge of light" zone of rapidly changing intensity. The light reflected from the surface is recorded by the detector, which is held at a constant position with respect to the light source.

The intensity of light is constant if the surface is smooth. As shown in Figure 2 (b), a change in slope appearing in the edge zone changes the angle at which the light is reflected from the surface. This changes the location of the detector in the "edge of light" band, which in turn changes the intensity of light appearing at the detector.

The Edge of Light scanner performance can be optimized for a particular application by expanding or compressing the edge zone, varying the angle of illumination, or changing the viewing angle. The scanner travels along the surface of interest, providing a high-resolution map of the surface topography.

Figure *3: The left half is an Edge of Light image of genuine (top) and counterfeit Canadian $20 bank notes. Covering the notes with aluminum foil removes any non-topographical features from the* **image.** *The fight half is a normal view of the same notes.*

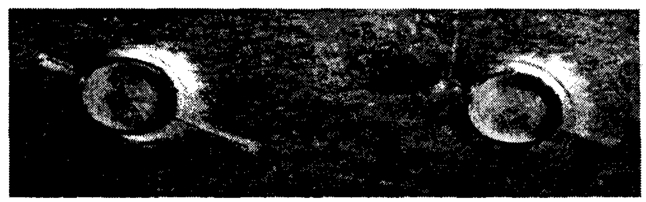


Figure *4:* **(a)** *Edge of Light image of two rivets from a Boeing 737. There are two cracks extending from each rivet. The rivet heads are about 7 mm in diameter.*

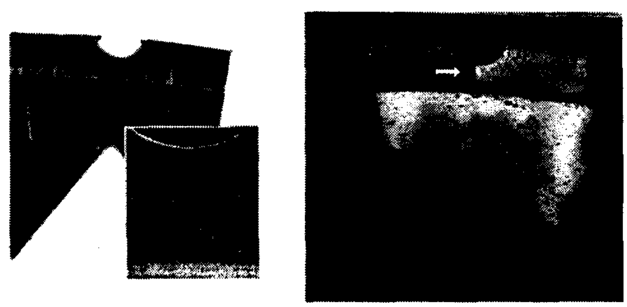
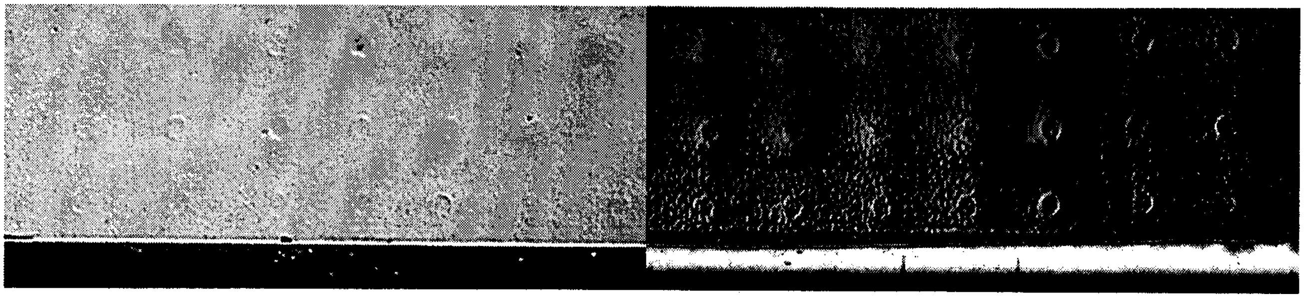


Figure *4: Section of a turbine disk with a bolt hole. On the left is an optical microscope image overlaid with an 30x magnification* **electron** *microscope* **image. On the right is an Edge of Light image,** *showing the fatigue crack not visible in the other images.*



Figures *5 (left) Lap splice joint from a Boeing 727, as seen by the unaided eye and* (right) *Edge of Light image of the same* lap *splice joint. Pillowing due to corrosion is evident in most of the Edge of Light image.*

Comparing Edge of Light and conventional NDI

A prototype Edge of Light scanner was used to inspect low cycle fatigue cracks in engine disk bolt holes, as shown in figure 4 (b). The results showed surface breaking cracks that were often not detectable using optical microscopy. The probability of detection (POD) of the inspection was calculated by opening the cracks. The Edge of Light scanner performed significantly better than either liquid penetrant, magnetic particle techniques, or optical microscopy for this application. Results from this study are available in "Edge of Light: a new enhanced optical NDI technique", D.S. Forsyth, A.Marincak, J.P. Komorowski, *Nondestructive Evaluation Techniques for Aging infrastructure & Manufacturing,* 2-5 Dec.1 995, Scottsdale, AZ, SPIE 2945, pp 178-188.

Pillowing

Deformation due to corrosion in lap joints of commercial airliners is accompanied by a bulging ("pillowing") between rivets, due to the increased volume of the corrosion product over the original material.

Figure 5 (right) shows an Edge of Light scan of a lap joint with corrosion. Most of the rivets in this half of the image appear to be raised from their surroundings, with lighter than ambient brightness on the left of the rivets and darker on the right. This is an optical illusion. The area between the rivets is actually higher than the rivet level due to corrosion pillowing; the maximum slope is at the edge of the rivets.

Opportunities

The National Research Council is working actively to develop licensing agreements and collaborative. development projects to apply the technology to a variety of testing options. Because Edge of Light is so easy to use and its images so easy to interpret, it shows great promise for applications in aging aircraft NDI, as well as in forensic studies. Licensees and collaborators can count on NRC research staff having the knowledge and expertise to find the right approach to a broad range of research challenges.

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