Best Practice Manual:

The Forensic Examination of Documents

ENFSI

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ENFSI's position on Best Practice Manuals

ENFSI wishes to promote the improvement of mutual trust by encouraging forensic harmonisation through the development and use of Best Practice Manuals. Furthermore, ENFSI encourages the sharing of Best Practice Manuals with the wider forensic science community, including organisations that are not ENFSI members.

In line with the Council Conclusions on the vision of the European Forensic Science Area 2.0 (EFSA 2.0), these manuals contribute to enhancing the quality, reliability and harmonisation of forensic practices across Europe, thereby strengthening mutual trust and the cross-border acceptance of forensic results.

Visit www.enfsi.eu/documents/bylaws for more information. This includes the ENFSI framework document Framework for the Process for the Creation of Technical Documents within ENFSI (QCC-FWK-001) and the Policy on Creation of Best Practice Manuals within ENFSI (QCC-BPM-001), which describe the principles, governance and procedures applicable to the development, review and publication of ENFSI Best Practice Manuals.

Official language

The text may be translated into other languages as required. The English language version remains the definitive version.

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Further information

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1. AIMS

This Best Practice Manual (BPM) aims to provide a framework of procedures, quality principles, training processes and approaches to the forensic examination of documents.

This BPM can be used by Member laboratories of ENFSI and other forensic science laboratories to establish and maintain working practices in the field of forensic document examination that will deliver reliable results, maximize the quality of the information obtained and produce robust evidence. The use of consistent methodology and the production of more comparable results will facilitate interchange of data between laboratories.

2. SCOPE

This BPM is aimed at experts in the field and assumes prior knowledge in the discipline. It is not a standard operating procedure and addresses the requirements of the judicial systems in general terms only.

Documents, of various types, are routinely encountered in casework and are required to be examined for a number of reasons (see Appendix 1 – Competencies for European Forensic Document Examiners). The examination of these documents may reveal information which is invaluable to the investigation of a crime, or which may provide evidence which indicates that a crime has been committed.

This BPM document addresses the entire forensic process for each of the above mentioned aspects; from the scene of crime to the presentation of evidence in the courts and so encompasses the systems, the procedures, the personnel, the equipment and the other requirements (e.g. storage conditions) for the whole spectrum of the process.

The law enforcement framework and the legal systems within which a forensic laboratory is working will determine the degree of direct control that individual practitioners have over each stage of a process. Where the practitioner is not directly involved in any particular stage they should still be in possession of sufficient knowledge to ensure the maintenance of good scientific practice.

3. TERMS AND DEFINITIONS

For the purposes of this Best Practice Manual (BPM), the relevant terms and definitions given in ENFSI documents, the ILAC G19 "Modules in Forensic science Process", as in standards like ISO 9000, ISO 17020 and 17025 apply. In this section only the field specific terms and definitions, which assist in the interpretation of this BPM, are listed.

Forensic Document Examiner - An individual that undertakes a Forensic Document Examination. This includes Reporting Scientists, Reporting Analyst and Analysts/Assistants.

Forensic Document Examination - The scientific examination and comparison of documents to determine whether the questioned document is genuine or counterfeited or fraud. Forensic Document Examination can be divided into two wider areas:

(a) the examination of security documents, including passports, identity documents (ID cards, breeder documents and other), driving licenses, vehicle documents, banknotes, and

(b) the examination of all other kinds of documents, including last wills, contracts, receipts, confirmations, threat letters.

Audit - a systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives.

Calibration - a set of operations that establish, under specified conditions, the relationship between values and quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realised by standards [International vocabulary of metrology – Basic and general concepts and associated terms: ISO/IEC Guide 99:2007 – 2.39]

Competence - a person's qualification for the job by virtue of their education, training and/or experience and demonstrated knowledge, skills and abilities.

Competence Test - a formal assessed check of an individual's performance against a predetermined expected outcome for specific examinations, measurements or procedures using material of known provenance.

Management/Administrative Review - review of a case file and report to ensure that the customer's needs have been properly addressed, compliance with laboratory policy and, for the report, editorial correctness.

Proficiency Test - the use of inter-laboratory comparisons to determine the performance of individual laboratories for specific tests or measurements and to monitor laboratories' continuing performance. [Conformity assessment – General requirements for the competence of proficiency testing providers: ISO/IEC 17043:2023 - 3.7]

Quality Assurance - All the planned and systematic activities implemented within the quality system, and demonstrated as needed, to provide adequate confidence that an entity will fulfill the requirements for quality. [Quality management systems – Fundamentals and vocabulary: ISO 9000:2015 – 3.3.6]

Quality Control - Operational techniques and activities that are used to fulfil the requirements for quality. [Quality management systems – Fundamentals and vocabulary: ISO 9000:2015 – 3.3.7]

Raw Data - the record of results of analysis and examinations in the form in which those results were interpreted by the original analyst.

Scientific/Technical Review - review of a case file and report for the reliability and interpretation of the scientific findings.

Systematic Error - any discrepancy due to improper instrument function.

Validation - Confirmation by examination and provision of objective evidence that the particular requirement for a specific intended use are fulfilled. [Quality management systems – Fundamentals and vocabulary: ISO 9000:2015 – 3.8.13]

4. RESOURCES

4.1 Personnel

People are likely to be the most important resource in any forensic application and in order to allow staff to work effectively, everybody concerned in the process must understand the nature of the tasks and the human qualities required to perform them.

Due to variations in the staffing of different laboratories and variability within different laboratory systems, absolute standardisation of staffing cannot be achieved. It is also accepted that an individual may be responsible for more than one of the defined roles. As such, it is acknowledged that Forensic Document Examiners will have a wide variety of experience, training and background knowledge. All of these can be obtained through a range of different processes but should include the criteria detailed in Appendix 1 - "Competencies for Forensic Document Examiners".

4.1.1 Roles and responsibilities

The key roles for Forensic Document Examinations are:

- Reporting Scientist – The forensic scientist responsible in a particular case for directing the examination of the items submitted, interpreting the findings, writing the report and providing evidence of fact, and opinion, for the court.
- Reporting Analyst – an analyst responsible in non-complicated cases (e.g. drugs analysis) for performing the examination of the items submitted, interpreting the analysis results, writing the analysis report and, if necessary, providing factual evidence for the court.
- Analyst/Assistant – An individual carrying out general casework examinations or analytical tests under the supervision of a Reporting Scientist and who is able to provide information to assist with the interpretation of the tests.

All these roles can be carried out by the same individual.

4.1.2 Competence requirements

The qualifications, competences and experience that individuals require to carry out the various aspects of Forensic Document Examination will depend on the intellectual and practical demands of the various aspects of the work. The manual defines the standards of competence required for individuals to undertake the particular aspects of work, the training required and the assessments that will be applied (see Appendix 1 - "Competencies for Forensic Document Examiners”).

Recommendably the following qualification, experience and areas of competence would be expected as the minimum standard for the key roles defined above, in forensic document examination:

- Reporting Scientist - a minimum of a Bachelor's degree (or equivalent) in a natural or applied science, or acceptance as an expert in the field through training and peer review, in the field of forensic document examination; knowledge of the theories, analytical techniques and procedures applicable to forensic document examination; competence in the evaluation and interpretation of findings in document cases; knowledge and experience of the requirements and procedures of the criminal justice system for the presentation of evidence, both written and oral
- Reporting Analyst - Knowledge of the theories, analytical techniques and procedures applicable to forensic document examination; competence in the evaluation and interpretation of analytical data in document cases; knowledge and experience of the requirements and procedures of the criminal justice system for the presentation of evidence, both written and oral
- Analyst/Assistant - Knowledge of the theories, analytical techniques and procedures applicable to forensic document examination; the practical skills to operate specialist equipment and to carry out forensic document analysis safely and reliably in compliance with laboratory protocols; an understanding of the requirements of the criminal justice system

4.1.3 Training and Assessment

The levels of training and assessment are dependent on the role being undertaken; however, the following should be addressed in developing a training and assessment programme:

- laboratories should have written standards of competence for each role, a documented training programme and processes for assessing that trainees have achieved the level of competence required;
- all training should be completed within the specified time frame and the outcome of assessments documented on the individual's training records;
- the assessment of competence can be accomplished through a combination of appropriate means, including:
    - practical tests
    - written and/or oral examinations
    - role exercises (for example "mock" courts)
    - casework conducted under close supervision
    - a portfolio of previous work

A trainee should only be recognised as competent when he or she has been assessed as meeting the defined standards of performance and only then be permitted to undertake independent casework in the relevant area. All personnel involved in the field of forensic document examination will also be required to demonstrate that they have maintained their competence at regular intervals, not exceeding 12 months (for example with the use of collaborative exercises or proficiency tests).

4.2 Equipment

The following equipment is a minimum requirement for a forensic document laboratory:

- Microscope(s)
- Light sources, incident, transmission, UV
- Electrostatic detection device
- Video spectral analyser

The equipment inventory should record the manufacturer, model, serial number, date of acquisition, date placed in service and location for each piece of equipment.

The manufacturer's operating manual for each item of equipment should be readily available at the workplace together with the repair and maintenance documents.

The performance of each item of equipment should be checked against reference standards materials as defined in the appropriate method.

Appropriate and properly operating equipment must be employed in casework, and then only operated in the limits of the performance checks.

4.3 Reference materials

- Databases (commercial, internal production, profession community production)
- Collections
- Materials submitted by the customer.

Usage of reference materials depends on the question, the item and the nature of document being examined. Some documents are examined without reference materials. For analysing of security documents, specimens, authentic comparative material and/or specialized informative databases are required. In some cases of authenticity verification the custumer is asked to present relevant reference material with guaranteed origin (e.g. original stamp impressions).

4.4 Facilities and environmental conditions

The principle considerations for forensic document examination are the need for sufficient, secure work space to allow for efficient and effective working and the need for good quality lighting, preferably natural daylight.

Consideration should be given to the need for special humidity controlled areas for electrostatic detection examinations. For special chemical examinations, like ink analysis or document dating, a chemical laboratory is required, including special storage equipment for documents.

When necessary correct anti-contamination procedures must be used to prevent cross-contamination. Cleaning of rooms and workspaces must be regulated and recorded.

4.5 Risk-Based Thinking

Risk assessment is an integral part of quality management as expressed in iSO 17025:2017. The laboratory shall consider risks and opportunities associated with both its impartiality and its laboratory activities, so that it can achieve its purposes and objectives in the intended way and can prevent or reduce undesired impact and potential failures.

The risk factors to be considered depend on the organization of the laboratory and the equipment used and should be based on the local standard operating procedures. Some of the more prominent risk factors to be assessed:

* Unwarranted deviation from the field of competence

Loss of traceability of samples and sub-samples

Representativity of samples

Lack of detection of significant traces

Threats to sample integrity

Inversion of samples

Bias in interpretation of findings

Peer review ability to detect errors.

This list is not comprehencive and should be regarded as an initial guide to monitor the processes conducted in laboratory. Risk assessment is a continuous process as external and internal risk factors tend to evolve both in likelihood and impact.

4.6 Materials and Reagents

All materials and reagents used in this field should be of a suitable quality and have been demonstrated to be fit for purpose.

Materials and reagents should be shown to be functioning correctly with a reference sample prior to their use in casework. The results of these tests should be recorded.

All materials, whether manufactured internally or obtained from external suppliers, should be labeled with their identity, concentration (if appropriate), date of preparation or receipt, date of opening, date of expiry and any special storage or safety requirements, if applicable, to comply with laboratory policy and/or appropriate regulations. The identity of the individual preparing reagents produced in the laboratory should also be recorded together with records of the preparation procedures.

5. METHODS

5.1 Examination Techniques and Methods

There is a wide range of Examination Techniques and Methods available to the Document Examiner. The principle of each method should be carried out in accordance with the recommendations in the appendices to this Manual (Appendix 2- Appendix 14).

An exemplary basic set of methods that shall be applied in the majority of case scenarios, questions and types of exhibits are:

- microscopic examination using different magnification (5x – 60x) and lighting conditions (oblique, transmitted, incident light)
- spectral video examinations, using different light sources and filters, together with video recording.
- detection of indented impressions
- chemical material analysis, such as thin layer chromatography of ink

5.2 Analysis Protocols

The actual work that is carried out in individual cases should be determined by the requirements of the case and will depend on the value of any other evidence which may be available. But a systematic approach should always be adopted, to ensure consistency of delivery of services that they are fit for purpose.

Whatever work is done, the Forensic Document Examiner should always use the combination of techniques available that offers the greatest potential for recovering any forensically viable information, taking into account the volume of work to be undertaken.

The choice of the most suitable methods of examination can only be made at the time of the initial assessment by the Forensic Document Examiner involved. Given the same case circumstances, all laboratories would ideally adopt the same analysis protocol, but in practice the extent to which such harmonisation can be achieved will be limited. This BPM can thus act only as a guide.

Nondestructive tests should be given priority.

5.3 Case Records

The exact requirements for recording casework information will depend on the legal system of the country/state of jurisdiction. As a minimum, however, the records should be in sufficient detail to allow another Forensic Document Examiner, competent in the same area of expertise, to be able to identify what has been done and to assess the findings independently.

For casework involving the forensic examination of documents, the records should include details of:

- the items that were submitted to the laboratory, the information accompanying the items on submission and the nature of the work requested;
- the method of submission (e.g. by hand, by post, etc.), by whom and on what date(s);
- all movement of casework material within the laboratory system, the person(s) responsible for the movement and the date(s) the movements took place;
- the method of return of items to the submitting organisation (e.g. by hand, by post, etc.), by whom and on what date(s);
- any changes, or additions to the items;
- all communications within the laboratory and between the laboratory and the submitting organisation about the case;
- for each item examined, the labeling, method of packaging and integrity of packaging on receipt;
- what examinations have been carried out, when, in what order, where and by whom;
- all observations made, photographs taken and analytical data generated;
- the specific examination methods and procedures used and the calibrations, standards and controls employed, or reference to where details of these can be found if they are held separately in a controlled system;
- all draft and final reports or statements generated;
- administrative and technical review, when and by whom.

Wherever possible, written records should be made on standardized forms.

6. VALIDATION AND ESTIMATION OF UNCERTAINTY

6.1 Validation and Verification

The laboratory should, where possible, only use validated or verified techniques and procedures for the forensic examination of documents and the interpretation of their significance in the context of the case.

Validation requires as a minimum that:

- there is an agreed requirement for the technique or procedure;
- the critical aspects of the technique or procedure have been identified and the limitations defined;
- the methods, materials and equipment used have been demonstrated to be fit for purpose in meeting the requirement;
- there are appropriate quality control and quality assurance procedures in place for monitoring performance;
- the technique or procedure is fully documented;
- the results obtained are reliable and reproducible;

- the technique or procedure has been subjected to independent assessment and, where novel, peer review.

Where the techniques or procedures have been validated elsewhere, the laboratory is required to carry out a verification exercise to demonstrate that it can achieve the same quality of results in its own environment.

6.2 Estimation of uncertainty of measurement

Uncertainty of measurement is applicable for examinations that include qualitative or quantitative analytical procedures. If physical or chemical measurements procedures are applied in forensic document examination then this estimation has to be performed according to state of the art error calculation routines. Validation data need to include values for uncertainty of measurement.

Whilst it can be accepted that Forensic Document Examiners do not routinely make the sort of measurements described in paragraph 7.6 of ISO 17025:2017 (refer to GUM which provides guidance to the expression of uncertainty), the standard indicates that: any laboratory should at least attempt to identify all the components of uncertainty and make a reasonable estimation of the uncertainty, which should be based on knowledge of the performance of the method. This should make use of for example, previous experience and validation data.

As such it is necessary to demonstrate that the issue of "uncertainty components" is addressed. Consideration should be given to each of these components when the Forensic Document Examiner is assessing the material as part of their examination.

7. QUALITY ASSURANCE

7.1 Proficiency testing/ Collaborative Exercises

Proficiency testing relates to the systems within the laboratory, but may also provide some information on the performance of individuals participating in the tests.

The documents section of the laboratory should participate in at least one externally generated proficiency test each year. Participants in the test should follow the standard laboratory procedures for casework. They should not give the test any special treatment that would not be given in the same circumstances to casework.

A list of currently available PT/ILC schemes as put together by the QCC is available at the ENFSI Website[1]. “FRAMEWORK FOR THE CONDUCT OF PROFICIENCY TESTS AND COLLABORATIVE EXCERCISES WITHIN ENFSI” provides information for the ENFSI Expert

[1] https://enfsi.eu/wp-content/uploads/2023/08/CQQ-FWK-004-PT-CE.pdf

Working Groups (EWGs) on how to organize effective proficiency tests (PTs) and inter-laboratory comparisons (ILCs) for their members.

The laboratory QA Manager should be informed of all PT/ILCs undertaken and QA Manager should ensure that the test is completed in a timely manner.

Any results not in accordance with the expected outcome should be brought to the attention of the laboratory QA Manager as soon as possible.

7.2 Peer Review

It is important within Forensic Document Examinations that the results of any examinations undergo Peer Review. This manual, therefore, details the requirements for Peer Review in the field of forensic document examinations and covers critical findings, together with both technical and management review aspects.

7.2.1 Critical findings

Whilst the exact legal requirements may be different for different organisations, in general findings of critical evidential value should be confirmed by a second Reporting Scientist who has been authorised and is competent to carry out such checks. Findings are considered critical when:

- they make a significant contribution to the findings in the case, and
- are incapable of being confirmed at a later time, or
- are subject to possible differences in interpretation by different scientists.

A written record of these checks should be made on the case notes, bearing the signatures of both the reporting scientist and the reviewer.

7.2.2 Technical findings

Details should be provided in the manual of the requirements for checking analytical findings and the raw data used in the interpretation of the findings in a particular case prior to the production of the report. The assessment made of these findings by the report writer and the conclusions drawn from them should be checked against the scientific findings to ascertain that they are justified and supported by documentation within the case file. Areas that should be covered by the technical review include:

- is there adequate documentation for all the materials examined;
- have the appropriate examinations/analyses been carried out;
- have the relevant QA procedures been followed;
- have analytical identifications/comparisons been checked;
- is the statement/report accurate and does it refer to all items submitted;
- are the conclusions reached justified and appropriate.

8. HANDLING ITEMS

All items submitted for documents examinations should first be examined for the integrity of their packaging. Any deficiency in the packaging, which may compromise the value of a laboratory examination, should be noted, and the customer be informed. Such a deficiency may be grounds for refusal to carry out the laboratory examination.

The examiner must ensure that any alterations to items within their possession are in accordance with the customer's requirements and are recorded within the case notes.

The examiner must ensure that, whilst within their possession, there is no contamination (for example extraneous fingerprints and/or DNA) to items that might require further examination. Where applicable staff should wear suitable protective clothing to minimise the risk of accidentally leaving trace evidence on the items being examined. Machines and workplaces have to be cleaned according to appropriate protocols.

The examiner must consider the potential health hazards with the item (see paragraph 13) and take the appropriate precautions when handling any relevant items.

All items for examination must be marked (e.g. by numbering stamp) for explicit identification. The marking is recorded in the written report. Exception from marking are security documents or some special valuable items where the customer don't agree with marking. These documents need to be packaged, stored and transported in a marked container, bag, etc., to avoid mixing-up.

9. INITIAL ASSESSMENT

9.1 Introduction

In general, all casework should undergo an initial case assessment to determine the suitability of the material for examination and the applicability of material submitted before any examination is undertaken.

9.2 Assessment at the laboratory

Before starting work on any case the examiner should carry out an assessment of the information available and the items provided for examination in light of the agreed customer requirement. The examiner should seek to redress any deficiencies through consultation with the customer. It is essential before starting any examination to understand, or agree with the customer the purpose of the examination requested. This should be expressed in terms of what the customer is seeking to establish rather than a menu of tasks to be carried out.

Protocols need to be in place therefore to determine:

- what information is being requested in respect of the submissions;
- the customer's priorities for the information;

- what other information is or may be available from the customer;
- what constraints may exist (e.g. the need to preserve material for other purposes, cost);
- the intended end use of the information, i.e. intelligence, evidential etc.

Any work carried out will be to meet a particular customer requirement. At each stage, however, it is important that the course of action selected is based on an assessment of both the propositions put forward by the customer and the known alternative(s) to this.

The examiner should also make an assessment of the risk of contamination, or any other issue that could affect the integrity of the items before examination commences.

The examiner should then consider to what extent the proposition put forward by the customer can be tested and should also frame at least one alternative proposition favourable to the 'defence'.

The examiner should consider what they might expect to find if each proposition were correct and should make an assessment of the likely strength of the findings.

10. PRIORITISATION AND SEQUENCE OF EXAMINATIONS

Where there is more than one item and/or evidence type involved in the examination of a case, then priorities and sequences for the examinations will need to be considered.

Before commencing any examinations within a case, the following matters should be considered:

- the urgency and priority of the customer's need for specific aspects of the information;
- the other types of forensic examination which may have to be carried out and whether examination for a particular evidence type or by a given examination technique will compromise subsequent examinations;
- which evidential types or items have the potential to provide the most information in response to the various propositions and alternatives;
- the perishable nature of any material that may be present;
- health and safety or security considerations.

10.1 Considerations for forensic document examinations

The Forensic Document Examiner must consider the most appropriate sequence of examinations, the implications of which will have to be considered in conjunction with:

- the availability of items for examination;
- the amount of material, within the items, available for examination;
- the number and nature of the different forensic document examination techniques that will be usable, dependant on the above;

- the potential value of the information available from each technique and which will provide the most information in response to the various propositions.

11. ASSESSMENT OF RESULTS AND INTERPRETATION

The same type of information is required for the evaluation and interpretation of the evidence found during the examination of a case as is required for the case evaluation undertaken before commencing any examination. Indeed, if the case evaluation has been carried out thoroughly the evaluation and interpretation of the case findings should be straightforward.

Evaluation and interpretation of the case findings will require consideration of:

- the background information available about the case and the original expectations formulated during case assessment;
- the significance of any information recovered;
- the limitations of the applied methods and procedures.

Evaluation shall follow the requirements described in the ENFSI guideline for evaluative reporting[2].

12. PRESENTATION OF RESULTS

12.1 General

The primary duty of those providing expert testimony, is to the court and to the administration of justice. As such, evidence should be provided with honesty, integrity, objectivity and impartiality.

Evidence can be presented to the court either orally or in writing. Only information which is supported by the examinations carried out should be presented. Presentation of evidence should clearly state the results of any evaluation and interpretation of the examination.

The Reporting Scientists findings and opinions are normally provided, in the first instance, in written form, as a report or statement of witness, for use by the investigator and/or the prosecutor/court. Oral evidence may subsequently be required.

12.2 Written presentation of evidence

Written reports should include all the relevant information in a clear, concise, structured and unambiguous manner, to make the task of assimilating the information as easy as possible. Written reports must be peer reviewed.

[2] https://enfsi.eu/wp-content/uploads/2016/09/m1_guideline.pdf

Whilst formal advice is available on the format of reports and statements the scope for consistency may be limited by the requirements of the criminal justice system for the country of jurisdiction. In general, however, the following should be included:

- the unique case identifier;
- the name and address of the laboratory(s) where the Forensic Document Examiner is employed;
- the identity of the Forensic Document Examiner(s), and evidence of their status and qualifications where this is a requirement;
- the signature of the Forensic Document Examiner(s);
- the date on which the report/statement of Forensic Document Examiner(s) was signed;
- the date of receipt of the material that has been examined;
- the name and status of the submitter;
- a list of the material submitted, identified by source;
- if relevant a comment relating to the condition of submitted material and its packaging when received, particularly where there is evidence of alteration, either by tampering, damage, contamination or any other means;
- details of all relevant information received with, or in addition to the material;
- the purpose of the examination;
- details of the examinations/analyses carried out;
- the results of the examination/analyses;
- an assessment of the significance of the results in the context of the information provided;
- Forensic Document Examiner(s) expert opinion, where appropriate, and any findings which may influence it;
- comment covering any material that was not examined, and the reasons for this;
- details of any submitted material, or parts of such material, not being returned to the submitter, and the reasons why.

The use of schedules and/or photographic charts or illustrations, including interpretations and original data, can be a helpful aid in presenting the information clearly.

Subjective or speculative interpretations should be avoided wherever possible.

12.3 Oral presentation of evidence

Persons expected to present oral testimony should have received instruction and/or mentoring in the procedural requirements of the particular criminal justice system in which the evidence is to be presented.

Only information which is supportable by the examinations carried out should be presented.

When giving oral evidence the Forensic Document Examiner should resist responding to questions that take them outside their field of expertise unless specifically directed by the court, and even then, a declaration as to the limitations of their expertise should be made.

13. HEALTH AND SAFETY

There are occasional health hazard issues with items submitted for forensic document examination, including biological contamination (for example excrement or biological powders) and chemical contamination (fingerprint treatment reagents). Caution must be taken when examining these types of items, personal protective equipment must be worn and occasionally no examination can be undertaken.

All necessary health and safety regulations for the application of specific methods and procedures need to be followed. Especially physical hazards, like UV-light, and chemical hazards for chemical analysis must be considered in individual laboratories regulatios.

14. REFERENCES

There are many books, journals and individual papers published on the subject of Document Examinations. It is impossible to compile a complete list of all of these. The following list contains some of the significant publications that relate to the examination of Documents.

14.1 Bibliography

- Ellen, D., The Scientific Examination of Documents - Methods and Techniques, Second Edition, Taylor& Francis press, London, 1997
- Kelly, J.S & Lindblom B.S., Scientific Examination of Questioned Documents, Second Edition, CRC press, New York, 2006
- Jürgens, M. C., The Digital Print Identification and Preservation. The Getty conservation Institute, Los Angeles, 2009
- Harrison, W.R., Suspect Documents. Sweet and Maxwell, London, 1958 and 1966
- Hilton, O., Scientific Examination of Questioned Documents. Elsevier, New York, 1982

14.2 Journals

- Journal of Forensic Sciences (American Academy of Forensic Sciences), Online ISSN 1556-4029
- Forensic Science International (Elsevier), ISSN 0379-0738
- Journal of the American Society of Questioned Document Examiners

14.3 References

- Guidelines for Best Practice in the Forensic Examination of Documents, EDEWG, Funded by the EU under project JHA/2000/OIS/013
- ENFSI guideline for evaluative reporting in forensic science, Version 3, 2015; funded by the EU ISEC 2010, Agreement Number: HOME/2010/ISEC/MO/4000001759
- Guidance on the conduction of Proficiency Tests and Collaborative Exercises within ENFSI, version 1, 2014; supported by EU ISEC 2009, Agreement Number: HOME/2009/ISEC/MO/4000000798

15. AMENDMETS TO PREVIOUS VERSION

	Approved Date	Details of Amendment
1	03.07.2026	Issue of original Best Practice Manual

APPENDIX 1 – COMPETENCIES FOR FORENSIC DOCUMENT EXAMINERS

This Competencies document is not written as a comprehensive guide to the examination of documents but is intended as a basis for the development of training programmes for the different aspects of Document Examination. Due to the fact that the field of Document Examination is so diverse it is often not possible for a Document Examiner to cover all aspects completely. Aspects dealt with within Document Examination are e.g. physical and chemical examinations of documents (paper, ink, toner, etc), classical and digital printing techniques, reproduction techniques, typewriting, alteration techniques, security features and the restoration of damaged documents. It is therefore possible and, in many instances, preferable that a Document Examiner would specialise in certain aspects of Document Examination and not attempt to perform all types of examination.

The units on the different aspects of Document Examination are divided into three main parts: the scope, the aspects requiring detailed knowledge and the aspects requiring awareness. However, if certain examination methods described under detailed knowledge are not performed personally by the Document Examiner due to the fact that these methods are not available or that they are performed elsewhere in the laboratory, a detailed knowledge may not be required and an awareness may be sufficient.

This appendix contains the following topics:

1. General Competencies
2. Devising an Examination Scheme
3. Performing Examinations
4. Interpretation of Results
5. Presenting evidence as an expert witness
6. UNIT 1. Basic knowledge and skills
7. UNIT 2. Alterations, obliterations, non-destructive ink comparison
8. UNIT 3. Paper examination
9. UNIT 4. Typewriting

10. UNIT 5. Reproduction and printing technology
11. UNIT 6. Stamps and stamp impressions
12. UNIT 7. Security Documents
13. UNIT 8. Sequencing
14. UNIT 9. Ink and toner analysis
15. UNIT 10. Dating of documents
16. UNIT 11. Opened and resealed envelopes
17. UNIT 12. Damaged documents
18. UNIT 13. Anonymous letters

GENERAL COMPETENCIES

SCOPE

Description of some general competencies required for a Forensic Examiner.

General Knowledge and understanding of ...	Where to learn?	How to test?
The limitations of ones own knowledge and ability	Literature[3], course, casework training	(court) Exam, case assessment
When and how to consult other experts in the same or adjoining fields.	Casework training, visit to other labs, conferences	Exam, case assessment
How and when to communicate with the police officer or district attorney in charge of the case	Casework training, police apprenticeship	Exam, case assessment
Whom the results of the examination are intended for and what the purpose is of the examination	Casework training	Exam, case assessment
How to estimate the maximum outcome of a case and the amount of work needed to be put into it	Casework training	Exam, case assessment
Relevant legislation and the principles of criminal law	Course	Law exam, court exam
The role of the Front Desk (case acceptance unit), the Forensic Advisor (intermediate between police and lab) and the Forensic Intake	Introduction to the Front Desk, casework training	case assessment
Basic statistics	Course, literature[4]	Exam statistics
Philosophy of Bayes Theorem and the formulation of hypotheses	Literature[5], course, casework training	Exam, case assessment

3 P. D. Barnett, “Ethics In Forensic Science Professional Standards For The Practice Of Criminalistics”. CRC Press, 2001, ISBN 0-8493-0860-7

4 B. Robertson, G.A. Vignaux "Interpreting Evidence: Evaluating Forensic Science in the Courtroom", John Wiley & Sons, 1995, ISBN: 0471960268

C.G.G. Aitken, F. Taroni "Statistics and the evaluation of evidence for forensic scientists", John Wiley & Sons; 2nd edition, 2004, ISBN: 0470843675

D. Lucy, Ïntroduction to Statistics for Forensic Scientist”, John Wiley & Sons; ISBN: 13 978-0-470-02200-9

5 C.G.G. Aitken, F. Taroni "Statistics and the evaluation of evidence for forensic scientists", John Wiley & Sons; 2nd edition, 2004, ISBN: 0470843675

A Stockton, S. Day, ”Bayes, Handwriting and Science”, Presentation at the Annual meeting of the ASQDE, August 2001

D. A. Rudram “Interpretation of scientific evidence”, Science & Justice Vol. 36 (1996), p. 133-138

I.W. Evett, “Towards a uniform framework for reporting opinions in forensic science casework”, Science & Justice; volume Vol.38 nr No.3 (1998), p. 198-202

P. Garbolino, F. Taroni, “Evaluation of scientific evidence using Bayesian networks”, Forensic Science International, 125 (2002) 149-155

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Bayes Theorem and the formulation of hypotheses, if used in casework reporting	Literature[6], course, casework training	Exam, case assessment
Principles of criminalistics within forensic science	Literature[7], course, casework training	Exam, case assessment
Contamination of evidence	Literature[8], course, casework training	Exam, court exam, case assessment
Quality assurance and health and safety aspects	Course, casework training	Exam, case assessment
Chain-of-custody requirements	Course, casework training	Exam, case assessment
Identification, labelling and conservation of evidence	Course, casework training	Exam, case assessment
The rules concerning the administration of casework results and other types of information within the discipline	Casework training	Case assessment
Casework administration	Casework training	Case assessment

Able to	Where to learn?	How to test?
Apply above knowledge to casework	See above	See above
Formulate hypotheses and counter-hypotheses	Course, casework training, course	Exam, case assessment, Exam statistics
Apply criminalistic principles to casework	Course, casework training	Exam, case assessment
Handle document evidence in such a way as to minimize the chance of contamination	Casework training	Exam, case assessment
Label and handle and transport document evidence in such a way that the contents are not compromised	Casework training	Exam, case assessment

6 See above

7 K. Inman, N. Rudin, "Principles and Practice of Criminalistics, The Profession of Forensic Science", CRC Press, 2000, ISBN: 0849381274

8 K. Inman, N. Rudin, "Principles and Practice of Criminalistics, The Profession of Forensic Science", CRC Press, 2000, ISBN: 0849381274

DEVISING AN EXAMINATION SCHEME

SCOPE

Description of the competencies required for a Forensic Examiner to devise a plan for the examination of document evidence.

General Knowledge and understanding of ...	Where to learn?	How to test?
Task and role of the Front Desk and the Forensic Intake	Casework training, Course	Exam, case assessment

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Rules for performing both routine and non-routine examinations	Course, casework training	Exam, case assessment
Circumstances of examination and types of evidence that may be expected	Literature[9], casework training	Exam, case assessment
Examination possibilities within the document's discipline	Literature[10], casework training	Exam, case assessment
Availability of equipment and facilities	Casework training	Exam, case assessment
Examination sequence and planning of examinations in both single and multi-disciplinary cases	Literature[11], casework training	Exam, case assessment
Adapting examination methods, including corrective measures (maintaining state of validation)	Course, casework training	Exam, case assessment
Value and completeness of the information and evidence obtained	Casework training	Case assessment
Information sources and their value	Casework training	Exam, Case assessment, court exam

9 O. Hilton, "Scientific Examination of Questioned Documents", CRC Press 1993, ISBN: 0849395100
J.S. Kelly, B.S. Lindblom, "Scientific Examination of Questioned Documents, second edition", CRC Press 2006, ISBN: 9780849320446
W.R. Harrison, "Suspect Documents: Their Scientific Examination", Nelson-Hall Publishers,1981, ISBN: 0882297597
J.V.P. Conway, "Evidential Documents", Charles C. Thomas, edition 1978, ISBN: 0398003424
D.Ellen, "The Scientific Examination of Documents: methods and techniques" Ellis Horwood Limited, 2nd edition 1997, ISBN: 0748405801

10 See above

11 Dunkerley, M.Y. and Riley, T.P., "The Effect of Fingerprint Powder Processing on E.S.D.A. Impressions", International Journal of Forensic Document Examiners, Vol. 5, Jan/Dec 1999, pp. 280-282.
Presley, L. A., Baumstark, A. L. and Dixon, A., "The Effects of Specific Latent Fingerprint and Questioned Document Examinations on the Amplification and Typing
of the HLA DQ alpha Gene Region in Forensic Casework," Journal of Forensic Sciences, JFSCA, Vol. 38, No.5, September 1993, pp. 1028-1036.

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Assumptions and limitations during the examinations and on interpretation of the results	Literature[12], casework training, course	Exam, case assessment, court exam, criminalistics exam
Formulating and weighing alternative hypotheses	Course, casework training, course	Exam, case assessment, Exam statistics

Able to	Where to learn?	How to test?
Apply above knowledge to casework	See above	See above
Devise an examination scheme minimising loss of evidence and maximising evidential value, taking both hypotheses into account	Course, Casework training	Exam, case assessment
Take part in a forensic intake	Casework training	Exam, case assessment

12 No specific literature, matter is dealt with in general in most scientific research papers

PERFORMING EXAMINATIONS

SCOPE

Description of the competencies required for a Forensic Examiner to perform the examination of document evidence.

General Knowledge and understanding of ...	Where to learn?	How to test?
The field of document examination	Literature[13], casework training	Exam, case assessment
Quality assurance issues related to casework	Casework training, course	Exam, case assessment, quality exam

Detailed knowledge and understanding of ...	Where to learn?	How to test?
The methods necessary to perform the examinations (see units)	Casework training	Exam, case assessment

Able to	Where to learn?	How to test?
Perform examinations including quality control	Casework training	Exam, case assessment
Check examinations, quality control and results obtained by another expert	Casework training	Exam, case assessment
Adapt examination methods and take corrective measures where necessary	Casework training	Exam, case assessment

[13] O. Hilton, "Scientific Examination of Questioned Documents", CRC Press 1993, ISBN: 0849395100J.S.
Kelly, B.S. Lindblom, "Scientific Examination of Questioned Documents, second edition", CRC Press 2006, ISBN: 9780849320446
W.R. Harrison, "Suspect Documents: Their Scientific Examination", Nelson-Hall Publishers,1981, ISBN: 0882297597
J.V.P. Conway, "Evidential Documents", Charles C. Thomas, edition 1978, ISBN: 0398003424
D.Ellen, "The Scientific Examination of Documents: methods and techniques" Ellis Horwood Limited, 2nd edition 1997, ISBN: 0748405801

INTERPRETATION OF RESULTS

SCOPE

Description of the competencies required for a Forensic Examiner to interpret the results of the examination of document evidence.

General Knowledge and understanding of ...	Where to learn?	How to test?
The limitations of ones own knowledge and ability	Literature[14], course, casework training	Exam, case assessment
When and how to consult other experts in the same or adjoining fields	Casework training, visit to other labs	Exam, case assessment
How and when to communicate with the police officer or district attorney in charge of the case	Casework training, police apprenticeship	Exam, case assessment
Whom the results of the examination are intended for and what the purpose is of the examination	Casework training	Exam, case assessment
Relevant legislation and the principles of criminal law	Course	Law exam, court exam
Basic statistics	Course, literature[15]	Exam statistics

Detailed knowledge and understanding of ...	Where to learn?	How to test?
The methods necessary to perform the examinations (see units)	Course, casework training	Exam, case assessment
All steps in the research process and the information gathered from previous examinations	Casework training	Exam, case assessment
Interpretation of data and results including all assumptions and limitations	Course, casework training	Exam, case assessment
Bayes Theorem and the formulation of hypotheses, if used in casework reporting	Literature[16], course, casework training	Exam, case assessment

14 P. D. Barnett, “Ethics In Forensic Science Professional Standards For The Practice Of Criminalistics”. CRC Press, 2001, ISBN 0-8493-0860-

15 B. Robertson, G.A. Vignaux "Interpreting Evidence: Evaluating Forensic Science in the Courtroom", John Wiley & Sons, 1995, ISBN: 0471960268
C.G.G. Aitken, F. Taroni "Statistics and the evaluation of evidence for forensic scientists", John Wiley & Sons; 2nd edition, 2004, ISBN: 0470843675
D. Lucy, Ïntroduction to Statistics for Forensic Scientist”, John Wiley & Sons; ISBN: 13 978-0-470-02200-9

16 K. Inman, N. Rudin, “Principles and Practice of Criminalistics, The Profession of Forensic Science”, CRC Press, 2000, ISBN: 0849381274

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Principles of criminalistics within forensic science	Literature[17], course, casework training	Exam, case assessment
Contamination of evidence, and chain of custody requirements	Literature[18], course, casework training	Exam, court exam, case assessment
Quality assurance	Course, casework training	Exam, case assessment
Identification, labelling and conservation of evidence	Course, casework training	Exam, case assessment
Rules concerning administration of casework results and other types of information within the discipline	Casework training	Case assessment

Able to	Where to learn?	How to test?
Collect present information and results	Casework training	Exam, case assessment
Check information and results	Casework training	Exam, case assessment
Draw founded conclusions	Casework training, Course	Exam, court exam, case assessment
Verbalize assumptions and limitations of the examination	Casework training, reporting course, court training	Exam, court exam, case assessment
Weigh additional information and hypotheses and adapt answers to include this	Casework training, court training	Exam, case assessment
Prepare a comprehensive report outlining your examinations and results	Casework training	Exam, case assessment

17 See above

18 K. Inman, N. Rudin, "Principles and Practice of Criminalistics, The Profession of Forensic Science", CRC Press, 2000, ISBN: 0849381274

REPORTING

SCOPE

Description of the competencies required for a Forensic Examiner to report the results of a document examination.

General Knowledge and understanding of ...	Where to learn?	How to test?
Terminology used in the field	Literature[19], casework training	Exam, case assessment
The use of a word-processor	Course	Case assessment

Detailed knowledge and understanding of ...	Where to learn?	How to test?
All steps in the research process and the information gathered from previous examinations	Casework training	Exam, case assessment
Rules for reporting	Casework training, course	Exam, case assessment
Interpretation of data and results including all assumptions and limitations	Course, casework training	Exam, court exam, case assessment
The end users and end purpose of the reports	Course, casework training	Exam

Able to	Where to learn?	How to test?
Write a report according to the laboratory guidelines	Course, casework training	Exam, case assessment
Structure a report	Literature[20], course, casework training	Exam, case assessment
Formulate your report in a logical and clear manner, legible both for experts as for laymen	Course, casework training	Exam, case assessment, court exam
Answer the questions asked	Course, casework training	Exam, case assessment court exam

19 The ASQDE Questioned documents glossary on www.asqde.org.
D. Brongers , R. Over de Linden, “Keesing’s Glossary of Document Security”, Keesing Reference Systems B.V., 2003, ISBN 90-5913-045-6

20 K. Inman and N. Rudin, Principles and Practice of Criminalistics, Chapter 11 “Communicating Your Results – Where Science Meets the Law”, CRC Press 2001, ISBN 0 8493-8127-4

PRESENTING EVIDENCE AS AN EXPERT WITNESS

SCOPE

Description of the competencies required for a Forensic Document Examiner to give evidence before court.

General Knowledge and understanding of ...	Where to learn?	How to test?
History of Forensic Document Examination	Literature (see Unit 1)	Exam, case assessment
Items described in General Competencies	See relevant section	Exam, case assessment
All relevant units	See relevant units	Exam, case assessment
The literature concerning the type of examination	Literature	Exam, case assessment
The effect that posture and attitude have on an audience	Court training	Court training

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Limitations of ones own knowledge and ability	Casework training	(court) Exam, case assessment
The specific methods used in the examination	Literature, casework training	Exam, case assessment
All steps in the research process and the information gathered from previous examinations	Casework training	Exam, case assessment
Philosophy of Bayes Theorem and the formulation of hypotheses if used in reporting	Literature, course, casework training	Exam, case assessment
Responsibilities of an Expert witness and the rules of evidence	Course, Court training	(court) Exam
Principles of criminalistics within forensic science	Literature[21], course, casework	Exam, case assessment
Contamination of evidence, chain of custody requirements and identification, labelling and conservation of evidence	Literature[22], course, casework training	(court) Exam, case assessment

21 K. Inman, N. Rudin, “Principles and Practice of Criminalistics, The Profession of Forensic Science”, CRC Press, 2000, ISBN: 0849381274

22 K. Inman, N. Rudin, “Principles and Practice of Criminalistics, The Profession of Forensic Science”, CRC Press, 2000, ISBN: 0849381274

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Quality assurance and health and safety aspects	Course, casework training	Exam, case assessment
The rules concerning the administration of casework results and other types of information within the discipline	Casework training	Case assessment
Manner of addressing the court, formulating, asking questions and presenting evidence	Court training	Court exam

Able to	Where to learn?	How to test?
Apply above knowledge to presenting evidence in court	See above	See above
Manufacture and use charts and other visual aids	Casework training, court training	Case assessment
Present evidence in court in a clear, logical, consistent, impartial manner, scientifically correct but understandable to non-scientists	Court training, course on reporting, case assessment	(court) Exam
Deal with questions asked by the defence concerning: ● all steps in the examination process; ● the discipline; ● criminalistics; ● limitations of the examination, the discipline and your own knowledge; ● alternative hypotheses; ● quality assurance in a non-defensive, honest and impartial manner.	Court training	(court) Exam
Ask for elucidation if questions are not clear	Court training	(court) Exam

UNIT 1 BASIC KNOWLEDGE AND SKILLS

SCOPE

Description of basic techniques required for the examination of documents. The techniques described here must be considered basic knowledge for all Document Examiners.

General Knowledge and understanding of ...	Where to learn?	How to test?
History of document examination	Literatur[23]	Exam
Terminology used in document examination	Literature[24], casework training	Exam
General possibilities and limitations of neighbouring forensic science disciplines · Handwriting comparison · General chemistry · Biology (e.g. DNA) · Fingerprint examination	Visits to other departments	Exam, case assessment

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Documentation techniques · Photography, Photocopying, Scanning	Literature[25], casework training	Exam, case assessment
Correct storage & treatment of materials · Protective storage · Labelling · Detrimental effect of fingerprint treatment on results of indented impression and other examinations	Casework training	Exam, case assessment

23 O. Hilton, "Scientific Examination of Questioned Documents", CRC Press 1993, ISBN: 0849395100
W.R. Harrison, "Suspect Documents: Their Scientific Examination", Nelson-Hall Publishers,1981, ISBN: 0882297597
J.V.P. Conway, "Evidential Documents", Charles C. Thomas, edition 1978, ISBN: 0398003424
D.Ellen, "The Scientific Examination of Documents: methods and techniques" Ellis Horwood Limited, 2nd edition 1997, ISBN: 0748405801

24 The ASQDE Questioned documents glossary on www.asqde.org.
D. Brongers , R. Over de Linden, "Keesing's Glossary of Document Security", Keesing Reference Systems B.V., 2003, ISBN 90-5913-045-6

25 General literature on document examination

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Examination methods · (Stereo)microscopy o Principles of microscopy o Lighting techniques o Contrasting techniques · General Lighting techniques o Transmitted, Specular, Oblique, Coaxial and Polarised light · Luminescence and reflection/absorption techniques o Fluorescence - Phosphorescence o Ultraviolet, Visible and Infrared light · Filter techniques o band-pass, short-pass, long-pass and polarisation filters	Literature[26], casework training	Exam, case assessment

Able to	Where to learn?	How to test?
Apply above knowledge to casework	See above	See above
Document evidence in such a way that relevant details can be retrieved	Casework training	Case assessment
Correctly label and store pieces of document evidence	Casework training	Case assessment
Examine a document using microscopy, luminescence and other filter techniques	Casework training	Case assessment

26 J. E. Costain, G. W. Lewis, “A Practical Guide to Infrared Luminescence Applied to Questioned Document Problems”, Journal of Police Science and Administration 1 (1973) pp. 209-218
M. Ellen, K. E. Creer, “Infrared Luminescence In The Examination Of Documents”, Journal Of The Forensic Science Society, Vol. 10 (1970), Pp.159-164
Sensi. C. A. and Cantu, A. A., “Infrared Luminescence: Is It a Valid Method to Differentiate Among Inks”, Journal of Forensic Sciences, Vol. 27, No. 1. Jan. 1982, pp. 196-199.
Cantu, A. A. and Prough, R. S., "Some Spectral Observations of Infrared Luminescence," Journal of Forensic Sciences, JFSCA, Vol. 33, No, 3, May 1988, pp. 638-647.

UNIT 2 ALTERATIONS, OBLITERATIONS, NON-DESTRUCTIVE INK COMPARISONS

SCOPE

All examinations where an alteration, addition or obliteration is suspected or where two or more inks are to be compared in a non-destructive manner.

This does not include inspection of these alterations additions and obliterations or use of ink comparisons to determine the sequence in which a document was completed, or to determine whether pages of a multi-page document has been substituted, removed or added. These are sequencing examinations and are covered in Unit [8]. It also does not include destructive analysis of inks to determine their chemical content Unit [9].

General Knowledge and understanding of ...	Where to learn?	How to test?
Methods of chemical and mechanical erasure	Literature[27], casework training	Exam, case assessment
Examination methods · X-ray transmittance · Scanning electron microscopy (could be partially destructive)	Literature[28], casework training	Exam, case assessment

27 R.Chowdhry, S.K.Gupta, H.L.Bami, "Detection and Decipherment of Erasures in Documents", Journal of Forensic Science Society, Vol. 16, No.2 (1976) pp. 139-150
J. Nickell, "Erasures and Corrections in Historic Documents: An Overview," International Journal of Forensic Document Examiners, Vol. 1, No. 3, July 1995, pp. 175-179.
Munden, E., Peszat, E. and B. Moyes, "Passport Forgeries -What to Look For, International Journal of Forensic Document Examiners, Vol. 1, No. 3, July 1995, pp. 186-200.
N. Safey El-Din, M.W. Sabaa, H. R. Hamed, "Influence of Chemical Erasures on the Different Types of Inks Marked on Document Papers" International Journal of Forensic Document
Examiners, Vol. 4, No. 2, April/June 1998, pp. 119-127.

28 D. S. Moore, "Evaluation of a Method Using Powder to Detect the Site of Rubber Erasures", Journal of Forensic Sciences, Vol. 26, No. 4 (1981) pp. 724-729
A.F. Hicks "Computer Imaging for Questioned Document Examiners II: The Potential for Abuse", Journal of Forensic Sciences, Vol. 40, No. 6 (1995) pp. 1052-1054
G.A. Szabo "Decipherment of Opaqued Writing with Scanning Technology", International Journal of Forensic Document Examiners, Vol. 3, No. 4 (1997) pp. 363-366
S. S. Kind, M. D. G. Dabbs, "The Use of Lycode Powders for the Detection of Erasures", Journal of the Forensic Science Society (1979). 19, pp.175
L. L. Shaneyfelt, "Obliterations, Alterations, and Related Document Problems", Journal of Forensic Sciences, Vol 16, No. 3, pp. 331-342

General Knowledge and understanding of ...	Where to learn?	How to test?
· Lycode powder for detection of traces of eraser or rub-down marks style catalogue of dry transfer lettering		
Knowledge described in other relevant units · Unit [8] sequencing examinations · Unit [9] ink and toner analysis	See relevant units	Exam, case assessment

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Microscopic and physical examination · Writing instruments, dry transfer lettering, basic printing and reproduction techniques · Mechanical erasure o Oblique or transmitted light, electrostatic detection apparatus · Chemical erasure o Fading, feel of the document, latent entries and impressions · Determination of stroke direction o Striations, build-up of ink · Determination of page or photo substitution	Literature[29], casework training	Exam, case assessment
General · Comparison material, paper translucency chemicals, electrostatic detection techniques	Literature[30], casework training	Exam, case assessment

29 O. Hilton, "Scientific Examination of Questioned Documents", CRC Press 1993, ISBN: 0849395100
J.S. Kelly, B.S. Lindblom, "Scientific Examination of Questioned Documents, second edition", CRC Press 2006, ISBN: 9780849320446
D.Ellen, "The Scientific Examination of Documents Methods and Techniques", Taylor & Francis, 1997, ISBN: 0748405801

30 O. Hilton, "Scientific Examination of Questioned Documents", CRC Press 1993, ISBN: 0849395100
J.S. Kelly, B.S. Lindblom, "Scientific Examination of Questioned Documents, second edition", CRC Press 2006, ISBN: 9780849320446
D.Ellen, "The Scientific Examination of Documents Methods and Techniques", Taylor & Francis, 1997, ISBN: 0748405801
C. E. H. Berger, J. A. de Koeijer, W. Glas, H. T. Madhuizen, "Color Separation in Forensic Image Processing", Journal of Forensic Sciences, (2006) Vol. 51, No. 1, pp.100-102

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Filtered light examination · IR reflection and luminescence behaviour, influence of substrate, line thickness, chemical, environmental conditions and ageing	Literature[31], casework training	Exam, case assessment
Digital image enhancement · Contrast stretching and colour deconvolution	Literature[32], casework training	Exam, case assessment
Knowledge described in other units ·Unit [3] Paper Examination ·Unit [5] Printing ·Unit [6] Stamps and stamp impressions ·Unit [7] Security Documents ·Unit [12] Damaged Documents	Literature[33], casework training	Exam, case assessment

Able to	Where to learn?	How to test?
Apply above knowledge to casework	See above	See above
Detect alterations to a document	Literature[34], casework training	Exam, case assessment
Examine obliterations of entries in a document	Literature[35], casework training	Exam, case assessment
Perform non-destructive ink comparisons	Literature[36], casework training	Exam, case assessment
Prepare comprehensive reports outlining your examinations and results	Casework training	Exam, case assessment

31 See above
32 See above
33 See above
34 See above
35 See above
36 See above

UNIT 3 PAPER EXAMINATION

SCOPE

All examinations in which paper is examined for a detailed comparison or to determine its origin. The ability to perform the destructive chemical and physical analyses described here will depend on the availability of these methods at a specific laboratory and the access to the instruments. The Document Examiners must however have a detailed understanding of these techniques, know when to apply them and be able to put the results of the analyses in a forensic context.

General Knowledge and understanding of ...	Where to learn?	How to test?
History of paper production	Literature[37]	Exam, case assessment
Existence of · Watermark databases · Specialised paper laboratories and the assistance that may be obtained	Literature[38], casework training	Exam, case assessment
Physical examinations · Fast Fourier Transform (FFT) filtering (to determine wire structure) · Microscopic examination of Pulp/fibre content o Fibre analysis/comparison · Microscopic examination of cross sections o Coating and Optical brighteners	Literature[39], casework training	Exam, case assessment

37 Pocket Pal, 50th Anniversary Edition, International paper Company, New York (1984)
Paper Knowledge, Book „ The Mead Corporation“ (1990)
D. Hunter, „Papermaking“, Book Dover Publications Inc (1978)

38 Technical University of Darmstadt, Alexanderstr. 8, 64283 Darmstadt, Germany

39 R. C. Johnson, „A Systematic Examination and Comparison of Paper Safety Matches“, Journal of Forensic Identification vol 42 No. 2 (1992) p 115 – 118
W. C. Krueger, „Paper Analysis in Forensic Sciences“, Identification News vol 22 No 11 (1972) p. 3 – 6
B. L. Browning, „Analysis of Paper“, Book Marcel Dekker inc. (1969) New York
W. J. Bodziak, „Edge Characteristics of Commercially Produced Paper Stock“, Journal of the ASQDE Vol 1 No 1 (1998) p 57 – 66
J. Grant, „Role of Paper in Questioned Document Work“, Journal of the Forensic Science Society Vol 13 No 2 (1973) p. 91 – 95
H. Miyata, M. Shinozaki, T. Enomae “A discrimination method for paper by Fourier Transform and Cross Correlation, Journal of Forensic Science Vol 47 No.5 (2002)

General Knowledge and understanding of ...	Where to learn?	How to test?
Separation methods for additives · Chromatographic techniques (TLC, HPLC)	Literature[40], casework training	Exam, case assessment
Micro-chemical spot analysis	Literature[41], casework training	Exam, case assessment
Elemental methods (inorganic analysis) · Scanning electron microscopy / energy dispersive x-ray fluorescence (SEM/EDX) · (µ-)X-ray fluorescence analysis · X-ray diffraction · Inductive coupled plasma / mass spectrometry (ICP-MS) · Isotope Ratio Mass Spectrometry (IRMS)	Literature[42], casework training	Exam, case assessment

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Paper manufacture · Fourdrinier process · Cylinder mould process	Literature[43], casework training	Exam, case assessment
Different types of paper · Plain paper, security paper, carbonless copy paper, carbon paper, plastic paper, etc.	Literature[44], casework training	Exam, case assessment

40 D. R. Rohilla, S. L. Mukhi, V. N. Sehgal, „Paper Identification by Spectrophotometric, Spectrofluorometric, and Chromatographic Analysis of Fluorescent Brighteners: A Case Study, Journal of
Police Science and Administration Vol 12 No 4 (1984) p. 385 – 389
A. H. Lyter, „Analysis for Water-Soluble Paper", Journal of Forensic Scienes Vol 25 No 2 (1980) p. 308 – 381

41 R. D. Blackledge, M. N. Gernandt, „The pH-Pen – a Means of Comparing Paper Products", Journal of Forensic Science Vol.38 No.1 (1993)

42 L. D. Space, R. B. Francis, U. Tinggi, „Comparison of the elemental composition of office document paper: Evidence in a homicide case", Journal of Forensic Science Vol. 47 No. 3 (2002)
A. van Es, J. de Koeijer, G. van der Peijl, "Discrimination of document paper by XRF, LA–ICP–MS and IRMS using multivariate statistical techniques", Science and Justice 49 (2009) 120–126.

43 Pocket Pal, 50th Anniversary Edition, International paper Company, New York (1984)
Paper Knowledge, Book „ The Mead Corporation" (1990)
D. Hunter, „Papermaking", Book Dover Publications Inc (1978)

44 See above

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Physical characteristics of paper · Thickness, grammage (Basis weight), luminescence, surface coating · The effect of humidity of the paper on its dimensions · Marks from cutting devices, grippers etc.	Literature7[45], casework training	Exam, case assessment
Watermarks · Watermark production methods · Watermark examination techniques · Recognition of the different types of watermarks · Methods of imitating watermarks	Literature[46], casework training	Exam, case assessment
Non-destructive physical examinations · Weighing and measuring, filtered light examination, physical match, fibre direction, transmitted light	Literature[47], casework training	Exam, case assessment

Able to	Where to learn?	How to test?
Apply above knowledge to casework	See above	See above
Explain the different manufacturing methods for paper and the paper security features	Literature, casework training	Exam, case assessment
Recognize the main types of paper	Literature, casework training	Exam, case assessment
Determine the physical characteristics of paper	Literature, casework training	Exam, case assessment

45 See above

46 See above

47 R. C. Johnson, „A Systematic Examination and Comparison of Paper Safety Matches“, Journal of Forensic Identification vol 42 No. 2 (1992) p 115 – 118
W. C. Krueger, „Paper Analysis in Forensic Sciences“, Identification News vol 22 No 11 (1972) p. 3 – 6
B. L. Browning, „Analysis of Paper“, Book Marcel Dekker inc. (1969) New York
W. J. Bodziak, „Edge Characteristics of Commercially Produced Paper Stock“, Journal of the ASQDE Vol 1 No 1 (1998) p 57 – 66
J. Grant, „Role of Paper in Questioned Document Work“, Journal of the Forensic Science Society Vol 13 No 2 (1973) p. 91 – 95
H. Miyata, M. Shinozaki, T. Enomae “A discrimination method for paper by Fourier Transform and Cross Correlation, Journal of Forensic Science Vol 47 No.5 (2002)

Able to	Where to learn?	How to test?
Recognize the different types of watermarks	Literature, casework training	Exam, case assessment
Examine paper using non-destructive methods	Literature, casework training	Exam, case assessment
Interpret evidence from chemical analysis of paper in a forensic context	Literature, casework training	Exam, case assessment
Perform the destructive chemical and physical analyses of paper used by your document section	Literature, casework training	Exam, case assessment
Prepare comprehensive reports outlining your examinations and results	Casework training	Exam, case assessment

UNIT 4 TYPEWRITING

SCOPE

All examinations in which a document produced using a machine with a fixed or single-element typeface is to be examined excluding letterpress printing. The purpose of the examination may be to determine how a document has been produced, whether two or more documents share a common origin, or whether a document has been, or could have been produced on a particular machine or if typewritten additions have been made. Covers the examination of conventional impact typewriters and associated items such as ribbons, print wheels, golf balls and other printing devices where the print-head is fixed, excluding rubber and metal stamps.

General Knowledge and understanding of ...	Where to learn?	How to test?
Categories of typewriter · Multi-element typewriters, golf balls, printwheels	Literature[48], casework training	Exam, case assessment
History of typewriters	Literature[49], casework training	Exam, case assessment
The effect of humidity of the paper on its dimensions	Literature[50], casework training	Exam, case assessment
Knowledge described in other units · Unit [5] reproduction and printing technology	See relevant units	Exam, case assessment

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Examination features	Literature[51], casework training	case assessment

48 O. Hilton, "Scientific Examination of Questioned Documents", CRC Press 1993, ISBN: 0849395100
J.S. Kelly, B.S. Lindblom, "Scientific Examination of Questioned Documents, second edition", CRC Press 2006, ISBN: 9780849320446
W.R. Harrison, "Suspect Documents: Their Scientific Examination", Nelson-Hall Publishers,1981, ISBN: 0882297597
D.Ellen, "The Scientific Examination of Documents: methods and techniques" Ellis Horwood Limited, 2nd edition 1997, ISBN: 0748405801

49 "The Story of the Typewriter 1873-1923" , Book, Herkimer County Historical Society, Herkimer, New York, 1923,
B. Bliven, "The Wonderful Writing Machine", Book, Random House, New York, 1954

50 E. Roh, J. Gremaud, "Influence of Relative Humidity on Paper", Kriminalistik und forensische Wissenschaften, nr. 83 (1994)p. 49-55

51 4 J.E. Behrendt and R.J. Muehlberger, "Printwheel Typescript Variations Caused by the Manufacturing Process", Journal of Forensic Sciences, Vol. 32, No. 3, May 1987, p. 629-639
M. J. Allen and R. A. Hardcastle, "The Distribution of Damage Defects Among Characters of Printwheel Typing Elements", Forensic Science International, 47, 1990, p. 249-259
J. Nemecek, "A Deep Look into Typewriter Alignment", Journal of Forensic Sciences, Vol. 10, No.1, January 1965, p. 23-34
M.J. Allen, and R.A. Hardcastle, " A classification scheme for Courier typestyles" , Journal of the Forensic Science Society, Vol. 30, No. 3 (1990), pp. 137-142

Detailed knowledge and understanding of ...	Where to learn?	How to test?
· Defects o Manufacturing defects and acquired defects (damages, misalignment, etc.) · Detection of additions or alterations to a typewritten document o Misalignments etc. · Ribbon analysis o Manual or automated o Matching typed character to a ribbon using paper fibres & mechanical fit · Correction methods o Correcting fluid and correcting ribbons		
Examinations methods · Macroscope / macroscope comparator, typewriters grid, type fonts database collections, automated ribbon analysis, digital imaging analysis	Literature[52], casework training	Exam, case assessment

Able to	Where to learn?	How to test?
Apply above knowledge to casework	See above	See above
Examine typewritten documents to determine (common) origin	Literature[53], casework training	Exam, case assessment
Examine typewritten documents to determine authenticity	Literature[54], casework training	Exam, case assessment

H.J. Shalley, "The association of lift-off tape with residual ink fracture outline by physical matching", Canadian Society of Forensic Science Journal, Vol. 27, No. 2 (1994), pp.59-67

A.G. Leslie, T.A. Stimpson, "Identification of printout devices", Forensic Science International, Vol. 19, No. 1 (1982), pp. 11-38

52 O. Hilton, "Scientific Examination of Questioned Documents", CRC Press 1993, ISBN: 0849395100

J.S. Kelly, B.S. Lindblom, "Scientific Examination of Questioned Documents, second edition", CRC Press 2006, ISBN: 9780849320446

W.R. Harrison, "Suspect Documents: Their Scientific Examination", Nelson-Hall Publishers,1981, ISBN: 0882297597

D.Ellen, "The Scientific Examination of Documents: methods and techniques" Ellis Horwood Limited, 2nd edition 1997, ISBN: 0748405801

53 See above

54 See above

Examine typewriter ribbons and correction ribbons	Literature[55], casework training	Exam, case assessment
Prepare comprehensive reports outlining your examinations and results	Casework training	Exam, case assessment

55 See above

UNIT 5 REPRODUCTION AND PRINTING TECHNOLOGY

SCOPE

All examinations in which machine produced text is examined, excluding text which has been produced using fixed or single element typewriters. The purpose of the examination may be to determine how a document has been produced, whether two or more documents share a common origin, or whether a document has been, or could have been produced on a particular machine. This unit covers the examination of industrial printing methods, impact dot matrix printers, thermal printers, inkjet and bubble jet printers, dye transfer printers, conventional and digital black and white and colour photocopiers, electrostatic printers and faxes, etc. They should be able to visit a printing scene and give advice on what samples to take away for further examination, and what is likely to be of little use.

General Knowledge and understanding of ...	Where to learn?	How to test?
History of the different printing, faxing and photocopying techniques	Literature[56], casework training	Exam, case assessment
The preparation of different kinds of printing forms (plates, screens, etc.)	Literature[57], casework training	Exam, case assessment
Other non-impact printing processes using toner	Literature[58], casework training	Exam, case assessment
Other printing techniques, e.g. Risography	Literature[59], casework training	Exam, case assessment
Operation and use of computers · Word processor software possibilities	Literature[60], casework training	Exam, case assessment

56 H. Kipphan, " Handbook of Print Media, Technologies and Production Methods", Springer Verlag 2001, ISBN: 3-540-67326-1
E.Webster, "Print Unchained – Fifty Years of Digital Printing, 1950-2000 and Beyond, A Saga of Invention and Enterprise" DRA of Vermont, Inc. 2000, ISBN: 0-9702617-0-5

57 H. Kipphan, " Handbook of Print Media, Technologies and Production Methods", Springer Verlag 2001, ISBN: 3-540-67326-1

58 H. Kipphan, " Handbook of Print Media, Technologies and Production Methods", Springer Verlag 2001, ISBN: 3-540-67326-1
D.L. Stevenson, "Handbook of Printing Processes", Graphic Arts Technical Foundation 1994, ISBN: 0-88362-164-9
F. Cost, "Pocket Guide to Digital Printing", Delmar Publishers 1997, ISBN: 0-8273-7592-1
U. Ley, G. Biscos, "Nonimpact Electronic Printing – The Reference Handbook", Interquest 1998
New Zealand Police, "Printing Processes Manual", Document Section Wellington Central Police Station.

59 H. Kipphan, " Handbook of Print Media, Technologies and Production Methods", Springer Verlag 2001, ISBN: 3-540-67326-1
New Zealand Police, "Printing Processes Manual", Document Section Wellington Central Police Station.

60 J.S. Kelly, B.S. Lindblom, "Scientific Examination of Questioned Documents, second edition", CRC Press 2006, ISBN: 9780849320446
W. L. Rosch, "Winn L. Rosch's Printer Bible" MIS Press 1996, ISBN: 1-55828-436-2

General Knowledge and understanding of ...	Where to learn?	How to test?
· How printers interact with computers (e.g. The effect of printer drivers on the printed document) · Different type of computer fonts		
Knowledge described in other units · Unit [4] typewriting · Unit [9] ink and toner analysis	See relevant units	Exam, case assessment

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Printing techniques (see below), the materials used and the characteristic features and printing defects	Course, casework training	Exam, case assessment
Conventional printing methods · Relief printing o Letterpress, dry offset or offset letterpress, flexography, hot foil stamping · Intaglio printing o Engraving, gravure · Planographic printing o Offset lithography · Screen printing	Course, literature[61], casework, training	Exam, case assessment
Impact printing · Dot-matrix printing and Typewriting (unit [4])	Literature[62], casework training	Exam, case assessment
Electrophotographic printing	Course, literature[63], casework training	Exam, case assessment

61 J. A. Blanco, "Identifying Documents Printed By Dot Matrix Computer Printers", Forensic Science International, 59 (1993) 35-47 35

62 W. L. Rosch, "Winn L. Rosch's Printer Bible" MIS Press 1996, ISBN: 1-55828-436-2

63 L.B. Schein, "Electrophotography and Development Physics", Laplacian Press 1992, ISBN: 1-885540-02-7
E.Williams, "The Physics and technology of Xerographic Processes", Krieger Publishing Company 1993, ISBN: 0-89464-772-5
U. Ley, G. Biscos, "Nonimpact Electronic Printing – The Reference Handbook", Interquest 1998
C.L. Gilmour and D.C. Purdy, "Colour printer operating systems and their identifying characteristics", Journal of the Forensic Science Society 1989: 29: 103-118.
M.W. Arbouine and S.P. Day, "The use of drum defects to link laser-printed documents to individual laser printers", Journal of the Forensic Science Society (1994) Vol 34. pp. 99-104.

Detailed knowledge and understanding of ...	Where to learn?	How to test?
· Laser, light emitting diode (led), liquid crystal shutter (lcs), electrostatic inks (indigo)		
Thermal printing · Direct thermal printers, wax thermal transfer, variable dot thermal transfer, dye sublimation thermal transfer	Course, literature[64], casework training	Exam, case assessment
Inkjet printing · Continuous inkjet · Drop-on-demand o Bubble jet/thermal liquid ink o Piezoelectric liquid · Solid inkjet/phase change	Course, literature[65], casework training	Exam, case assessment
Faxes	Course, literature[66], casework training	Exam, case assessment

R. S. Winter, "The Detection of Laser Printer Defects for Printer Identification", Presented at the Annual Meeting of the American Society of Questioned Document Examiners Ottawa, Canada -August, 2000
Buglio. J., "Association of Document and Laser Printer by Means of Residual Toner Impressions," International Journal of Forensic Document Examiners, Vol. 5, Jan/Dec 1999, pp. 365-370.
J. S. Tweedy, " Class Characteristics of Counterfeit Protection System Codes of Color Laser Copiers", of the American Society of Questioned Document Examiners, Vol.4, No.2, December 2001, pp.53
C.L. Gilmour, "A Comparion of Laser Printed and Photocopied Documents, Can they be Distinguished?", Journal oi the Canadian Society of Forensic Science, Vol.27, No.4 (1994) pp. 245-259
G. M. LaPort, R. S. Ramotowski, "The Effects of Latent Print Processing on Questioned Documents Produced by Office Machine Systems Utilizing Inkjet Technology and Toner", Journal ofn Foren sic Science, May 2003, Vol. 48, No. 3, pp. 1-6,

64 G. M. LaPorte, J. D. Wilson, S. A. Mancke, J. A. Payne, R. S. Ramotowski, S. L. Fortunato, "The Forensic Analysis of Thermal Transfer Printing", Journal of Forensic Sciences, September 2003, Vol. 48, No. 5
J. Brandi, J. Ganas, " Positive image retrieval from used thermal transfer printer rolls", Journal of Forensic Document Examination. Volume I I. Fall. 1998 pp 101 -114.

65 S.F.Pond, "Inkjet Technology and Development Strategies", Torrey Pines Research 2000
S. P. Day, L. Shufflebottom, "Evidential Value From Ink-Jet Printers", presented at the 2nd EAFS meeting, Krakow, September 2000
W. L. Rosch, "Winn L. Rosch's Printer Bible" MIS Press 1996, ISBN: 1-55828-436-2
P. Doherty, "Classification of Inkjet Printers and Inks", Journal of the American Society of Questioned Document Examiners, Vol.1, No.2, December 1988, pp.88
U. Ley, G. Biscos, "Nonimpact Electronic Printing – The Reference Handbook", Interquest 1998
H.P. Le, "Progress and trends in Ink-jet Printing Technology", Journal of Imaging Science and Technology 42, 1998, pp. 49-62
Andreottola, M. A., "Basic Inkjet Printing," Journal of Forensic Document Examiners, Vol. 5, Jan/Dec 1999, pp. 285-289
G. M. LaPort, R. S. Ramotowski, "The Effects of Latent Print Processing on Questioned Documents Produced by Office Machine Systems Utilizing Inkjet Technology and Toner", Journal of Forensic Science, May 2003, Vol. 48, No. 3, pp. 1-6,

66 M. Casey Owens, "A Look into Facsimile Transmission," Journal of Forensic Sciences, Vol. 35, No. 1, Jan. 1990, pp. 112-117
P. Westwood, M. Novotny, " Dating and Sourcing a Questioned Facsimile Document - TTI Pitfall", Presented at the 58th General Meeting of the ASQDE, 25 to 29 August 2000, Ottawa, Canada
J. A. Lauterbach, "A Collection of Fax Fonts Part III & Fax Font Database", Presented at the Annual Meeting of the American Society of Questioned Document Examiners Ottawa, Canada - August, 2000
M. Reed, The Transmission Marker: An Overlooked Feature Of Facsimile Machines", Presented At The 54th Annual Meeting Of The American Society Of Questioned Document Examiners, Washington, Dc August 1996.

Detailed knowledge and understanding of ...	Where to learn?	How to test?
· Major categories of faxes machines (thermal, laser, ink-jet etc.) · The basics steps of facsimile process · Fax header identification, possible defects and identification marks		
Photocopiers · The difference between the analogue and digital photocopier process · Recognition of generation photocopies of an original document · Colour copiers and colour laser printers and their security features (Bitmap codes)	Course, literature[67], casework training	Exam, case assessment
Finishing of printing products case assessment · Cutting, folding and binding	Course, casework training	Exam, case assessment
Reproduction technology / desktop publishing · Reproduction photography, Scanning techniques · Screening techniques o Halftone screening, Frequency modulation screen	Course, literature[68], casework training	Exam, case assessment
Organisation of and equipment in a printing shop	Course, casework training	Exam, case assessment
Examination methods	Course, literature[69], casework training	Exam, case assessment

Seaman Kelly, J., "Facsimile Documents: Feasibility for Comparison Purposes", Journal of Forensic Sciences, Vol. 37, No. 6, November 1992, pp. 1600-1609.

67 R. A. Horton, "Identifiability of the Flatbed Scanner and Its Products (Graphics Files and Printed Results)", Journal of the American Society of Questioned Document Examiners, Vol.3, No.1, June 2000, pp.41
R. Gervais, "A Study of Photocopier Distortion Through Interactive Animations", Presented at The American Society of Questioned Document Examiners Annual Conference, August 11-16, 2005 Montreal, Quebec
F.J. Gerhart, "Identification of Photocopiers from Fusing Roller Defects", Journal of Forensic Sciences Vol.37, No.1, Jan.1992, pp. 130-139 See Electrophotographic printing

68 R. A. Horton, "Identifiability of the Flatbed Scanner and Its Products (Graphics Files and Printed Results)", Journal of the American Society of Questioned Document Examiners, Vol.3, No.1, June 2000, pp.41
W. L. Rosch, "Winn L. Rosch's Printer Bible" MIS Press 1996, ISBN: 1-55828-436-2
H.R. Kang, "Digital Color Halftoning", IEEE Press 1999, ISBN: 0-7803-4741-2

69 B. Gascoigne, "How to Identify Prints", Thames and Hudson 1995, ISBN:0-500-23454-x New Zealand Police, "Printing Processes Manual", Document Section Wellington Central Police Station.

Detailed knowledge and understanding of ...	Where to learn?	How to test?
· Microscopic recognition of non-impact printing methods and materials · Microscopic recognition of impact printing methods and materials · The possible defects and identification marks o Manufacturing defects (indentation of roller marks, etc.) o Acquired defects (such trash marks, drums defects, indentations from toner accumulation on roller defects, satellite dots etc.) · Detection of additions or alterations to a photocopied/printed document · Toner analysis and comparison (unit [9])		
Knowledge described in other units · Unit [3] Paper examination · Unit [7] Security documents	See relevant units	Exam, case assessment

Able to	Where to learn?	How to test?
Apply above knowledge to casework	See above	See above
Recognise conventional and other printing techniques	Course, literature[70], casework training	Exam, case assessment
Examine printed documents to determine (common) origin	Course, literature[71], casework training	Exam, case assessment
Examine printed documents to determine authenticity	Course, literature[72], casework training	Exam, case assessment

L.A. Mohammed, G.G. Jenkinson, "Association of counterfeit documents to a printing plate by means of halftone dots", Journal of the American Society of Questioned Document Examiners 2002, 11-19
C. E. H. Berger, J. A. de Koeijer, W. Glas, H. T. Madhuizen, "Linking Inkjet Printing to a Common Digital Source Document", Journal of the American Society of Questioned Document Examiners, Vol.8, No.2, December 2005, pp.91
Relevant EDEWG method - Recognition of Printing Techniques

70 See above

71 See above

72 See above

Advise on evidence collection from a suspect printing shop	Course, literature[73], casework training	Exam, case assessment
Prepare comprehensive reports outlining your examinations and results	Casework training	Exam, case assessment

UNIT 6 STAMPS AND STAMP IMPRESSIONS

SCOPE

All examinations in which stamps, or impressions from stamps are involved, in particular comparison of stamps with stamp impressions to determine whether there is a link between them.

General Knowledge and understanding of ...	Where to learn?	How to test?
Knowledge described in other units · Unit [5] reproduction and printing technology Examination methods · Spectroscopic methods (microspectrophotometry, FTIR, Raman spectroscopy, X-ray fluorescence) · Chromatographic techniques (GC, TLC, HPLC)	See relevant units	Exam, case assessment

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Types of stamps · Rubber stamps o Appearance, manufacture (including stamp kits using photosensitive polymers), types of inks, computer aided generation of stamps · Inked metal stamps o Manufacture, appearance, types of inks · Dry metal or embossing stamps	Literature[74], casework training	Exam, case assessment

73 See above

74 J. S. Kelly "Forensic Examination of Rubber Stamps, A Practical Guide", Charles C Thomas, 2002, ISBN: 0398072795
G. Herbertson "Rubber Stamp Examination, A Guide for Forensic Document Examiners", Wide Line Publishing, 1997

Detailed knowledge and understanding of ...	Where to learn?	How to test?
o Manufacture, appearance		
Transfer of stamp impressions · Faults & damage: manufacturing defects, acquired defects, features of normal wear	Literature[75], casework training	Exam, case assessment
Examination methods · Non-destructive methods o Microscopic examination of stamp dyes and impressions o Overlay of stamp impressions (transparencies, digital overlay, comparator o Filtered light examination	Literature[76], casework training, training courses by equipment manufacturers	Exam, case assessment

Able to	Where to learn?	How to test?
Apply above knowledge to casework	See above	See above
Recognise stamps made by different techniques	Literature[77], casework training	Exam, case assessment
Examine stamped documents to determine (common) origin	Literature[78], casework training	Exam, case assessment
Examine stamped documents to determine authenticity	Literature[79], casework training	Exam, case assessment
Prepare comprehensive reports outlining your examinations and results	Casework training	Exam, case assessment

75 M. A. Casey, "The Individuality of Rubber Stamps", Forensic Science International Vol. 12, No. 2 (1978) pp. 137-144
H. Seiden, "Rubber Stamps: Revisited", International Journal of Forensic Document Examiners Vol. 4, No. 1 (1998) pp. 58-60

76 T.D.Chaplin, R.J.H. Clark, D.R.Beech "Comparison of Genuine (1851-1852 AD) and Forged or Reproduction Hawaiian Missionary Stamps using Raman Spectroscopy", Journal of Raman Spectroscopy Vol. 33 (2002) pp. 424-428

77 See above

78 See above

79 See above

UNIT 7 SECURITY DOCUMENTS

SCOPE

Examination of documents with special security devices (passports, cheques, loan papers etc.). The ability to perform the destructive chemical and physical analyses described here will depend on the availability of these methods at a specific laboratory and the access to the instruments. The Document Examiners must however have a detailed understanding of these techniques, know when to apply them and be able to put the results of the analyses in a forensic context.

General Knowledge and understanding of ...	Where to learn?	How to test?
Knowledge described in other units Unit [3] paper examination Unit [5] reproduction and printing technology Unit [6] examination of stamps and stamp impressions	See relevant units	Exam, case assessment
The design aspects of security documents	Literature[80], casework training	Exam, case assessment
Developments in the key documents, such as ID-documents, banknotes, driving licences, etc.	Literature[81], casework training	Exam, case assessment
The existence of · Databases on security documents(e.g. EDISON, FADO) · Reference collections of security documents · Information sheets on security documents	Literature[82], casework training	Exam, case assessment
Examination methods · Non-destructive methods	Literature[83], casework training	Exam, case assessment

80 Keesing Journal of Documents and Identity", Keesing Reference Systems
Keesing's Glossary of Document Security", Keesing Reference Systems
The Catalogue of Currencies" (electronic form) , APIS Ltd. Slovakia

81 Ten new EU Members, ten new Passports; Keesing's Journal of Documents; Issue 5, 2004
R.L. van Renesse, "Optical Document Security", Artech House, Inc., 1994, ISBN: 0-89006-619-1

82 Various document alerts from different organisations such as: The BKA (Germany), the Royal Marrechaussee (Netherlands), Canada Border Services Agency, INS (USA), IS National Forgery Section (UK)

83 See literature in other dedicated sections

General Knowledge and understanding of ...	Where to learn?	How to test?
o X-ray transmittance for watermarks o Spectroscopic methods (microspectrophotometry, FTIR, Raman Spectroscopy, X-ray fluorescence) for inks and laminates · Destructive methods o Chromatographic techniques (GC, TLC, HPLC) o Hyphenated Techniques (e.g. Pyrolysis-Gas Chromatography-Mass Spectrometry (Pyr.-GC/MS) for laminates		

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Security paper · Watermarks, fibres, ingraining, threads, planchettes, chemical agents	Literature[84], casework training	Exam, case assessment
Security printing · Secure printing techniques o Intaglio, rainbow printing, guilloches · Security inks o Fugitive inks, UV inks, IR inks, metamere inks, optically variable inks, iridescent inks etc. · Printed anti-copying devices o Screen angle modulation (SAM, μSAM), frequency modulation, latent images, printed ovd's, scrambled indicia · Laser engraving and perforation o Microperf	Literature[85], casework training	Exam, case assessment

84 M.B.M Oude Valdhuis, H. van Zanten, "Document Security, Training for professionals", Keesing Reference Systems, 2001, ISBN: 90-805837-8-2
R.L. van Renesse, "Optical Document Security", Artech House, Inc., 1994, ISBN: 0-89006-619-1
85 R.L. van Renesse, "Optical Document Security", Artech House 1994, ISBN: 0-89006-619-1

Detailed knowledge and understanding of ...	Where to learn?	How to test?
· Security devices o Optical variable devices, e.g. Kinegrams and Holograms o Laminates		
Examination methods · Non-destructive methods o Microscopic examination o Filtered light examination	Literature[86], casework training, training courses by equipment manufacturers	Exam, case assessment

Able to	Where to learn?	How to test?
Apply above knowledge to casework	See above	See above
Recognise and examine different secure printing techniques and security devices	Literature[87], casework training	Exam, case assessment
Prepare comprehensive reports outlining your examinations and results	Casework training	Exam, case assessment

86 See literature in other dedicated sections

87 R.L. van Renesse, "Optical Document Security", Artech House, Inc., 1994, ISBN: 0-89006-619-1

UNIT 8 SEQUENCING

SCOPE

All examinations where it is required to establish in which order two or more marks on a document were made. This includes the sequencing of inks, typewriting and printed material. It also includes examinations where it is required to establish whether or not pages within a document have been substituted, removed or added.

General Knowledge and understanding of ...	Where to learn?	How to test?
Examination methods · Confocal microscopy[88] · Scanning Electron Microscopy (SEM)[89] · 3D-Microscopy[90] · Laser scanning profilometry[91] · TOF-SIMS[92]	Literature, casework training	Exam, case assessment

88 W. Ruml, "Welcher von zwei sich kreuzenden Tintenschriftzügen ist der später geschriebene?", Arch. f. Kriminologie 116: 15 - 18, 1955
S. Oehlinger, "Neue Möglichkeiten zur Untersuchung von Strichkreuzungen unter besonderer Berücksichtigung von Kugelschreiberschriften", Arch. f. Kriminologie 115: 130 - 132, 1955
W. Hofmann, "Die Kreuzung zwischen Schreibmaschinen- und Kugelschreiberschrift", Kriminalistik: 290 - 295, 1959
B. A. Megevand, P. A. Humi, J. A. Tappolet and J. Mathyer, "Determining the Sequence of two Intersecting Lines, one of which has been typed with a correctable ribbon", International Criminal Police Review 401: 217 - 222, 1986
E. Diekmann, "Praktische Hinweise zur Untersuchung von Strichkreuzungen unter besonderer Berücksichtigung von Farbbandschriften", Arch. f. Kriminologie 179: 100 - 113, 1987
H. J. Hill and J. R. Welch, "The Sequencing of Entries on multi-part carbonless Sets", J. For. Sci. Soc. 34: 221 - 224, 1994
K.C. Cheng, C.H. Chao, B.S. Jeng, S.T. Lee, “A new method of identifying writing sequence with the laser scanning confocal Microscope”, Journal of Forensic Sciences 1998, Vol.43 (2), pp.348-352.

89 L. Godown, "Recent Developments in Writing Sequence Determination", For. Sci. Int. 20: 227 - 232, 1982
P. J. Nolan, C. Davies ang A. G. Filby, "Determination of Sequence of Writing - a Strategy for Evaluation new Methods", IAFS - Meeting Oxford: 1 - 14, 1984
A. Blueschke and A. Lacis, "Examination of Line Crossings by Low KV Scanning Electron Microscopy (SEM) using Photographic Stereoscopic Pairs", Journal of Forensic Sciences 41: 80 - 85,
J. Mathyer, "The problem of establishing the sequence of superimposed lines - Critical review of proposed techniques", 6th Interpol Forensic Science Symposium, 1980
P. A. Waeschle, "Examination of Line Crossings by Scanning Electron Microscopy", Journal of Forensic Sciences 24 (3): 569 - 578, 1979

90 P.X. Iten, "Fortschritte in der Kriminaltechnik", Kriminalistik: 156 - 163, 1981

91 Jan de Kinder and Veerle Berx," The Application of Profilometry in the Analysis of the Lines Crossing", Journal of the American Society of Questioned Document Examiners 8: 1 - 8, 2005
Kun - Chi Cheng, Chi - Hsiang Chao, Bor - Shenn Jeng and Shing - Tsai Lee, "A new Method of Identifying Writing Sequence with the Laser Scanning Confocal Microscope", J. For. Sci. 43 (2): 348 - 352, 1998
G. S. Spagnolo, C. Simonetti and L. Cozzella, "Superposed Strokes Analysis by Conoscopic Holography as an Aid for a Handwriting expert", I. Opt. A: Pure Appl. Opt. 6: 869 - 874, 2004
G. S. Spagnolo, “Potentiality of 3D laser profilometry to determine the sequence of homogenous crossing lines on questioned documents”, Forensic Science International 164 (2006), pp.102–109

92 S.J. Pachuta, J.S. Staral, "Nondestructive Analysis of Colorants on Paper by Time-of-Flight Secondary Ion Mass Spectrometry”, Analytical Chemistry, Vol. 66, 1994, pp. 276-284.
J.A. de Koeijer, “TOF-SIMS, a possible solution to some forensic problems: determining the sequence of a handwritten entry and a fingerprint or of entries from two different ballpoint pens”, Poster presented at the European Academy of Forensic Science Meeting in Helsinki, 2006.

General Knowledge and understanding of ...	Where to learn?	How to test?
· others[93]		

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Physical characteristics · the morphology and physical characteristics of ink and toner · the effect of stroke intensity differences · the effect of stroke pressure differences	Literature[94], Casework training	Exam, case assessment
The examination sequence · non-destructive techniques first and the limitations of lifting techniques	Casework training	Exam, case assessment
Examination methods · Non-destructive techniques o Stereo microscope with reflection (different incident light angles) and transmission illuminations (white light) both paper sides: examination of the morphological structures of inks on paper (writing inks, ribbon inks, stamp inks, toner, inkjet inks etc.) o Microscopical observation with different light sources and filters (VIS. - IR luminescence & IR reflection) o Reflected-light microscope with different filters (magnification range 100x - 1000x) · Destructive techniques	Literature[96], Casework training	Exam, case assessment

93 S. Kasas, A. Khamny - Vital and G. Dietler, "Examination of Line Crossing by Atomic Force Microscopy", For. Sci. Int. 119: 290 - 298, 2001
Jaap van der Weerd, Marieke K. van Veen, Ron M. A. Heeren and Jaap J. Boon, " Identification of Pigments in Paint Cross Sections by Reflection Visible Light Imaging Microspectroscopy", Anal. Chem. 75: 716 - 722, 2003

94 V.N. Aginsky, "Determining the Sequence of Non-Intersecting Media on Documents - Ballpoint pen ink and laser toner entries", Presented at the Annual Meeting of the American Society of Questioned Document Examiners Des Moines, USA - August, 2001
Michelle Novotny and Paul Westwood, "Determining the Sequence of Original Ink Writing and Toner Printing", Journal of the American Society of Questioned Document Examiners 8: 37 - 47, 2005

96 L. J. Hart and B. B. Carney, "Typewriting versus Writing Instrument: A Line Intersection Problem", Journal of Forensic Sciences 34: 1329 - 1335, 1989
G. Poulin, "Establishing the Sequence of Strokes: The State of the Art," International Journal of Forensic Document Examiners, Vol. 2, No. 1, Jan/Mar 1996, pp. 16-32.

Detailed knowledge and understanding of ...	Where to learn?	How to test?
o Various instrumental techniques described under general knowledge o Chemical transfer techniques (Kromekote paper lifting etc.)[95]		

Able to	Where to learn?	How to test?
Apply above knowledge to casework	See above	See above
Recognise writing and printing techniques by their physical characteristics	Literature see above), casework training	Exam, case assessment
Apply the methods at hand to the determination of the sequence of strokes in the right order	Literature see above), casework training	Exam, case assessment
Determine the reliability of the techniques applied		
Prepare comprehensive reports outlining your examinations and results	Casework training	Exam, case assessment

95 R. D. Koons, "Sequencing of intersecting Lines by combined Lifting Process and Scanning Electron Microscopy", For. Sci. Int. 28: 261 - 276, 1985
S.C. LEUNG, Y.M. LEUNG, "A systematic study of the lifting technique for determining the writing sequence of intersecting ball pen strokes", Science & Justice 1997, Vol. 37 pp. 197-206
G. Poulin, "Establishing the Sequence of Strokes: The State of the Art," International Journal of Forensic Document Examiners, Vol. 2, No. 1, Jan/Mar 1996, pp. 16-32.

UNIT 9 INK AND TONER ANALYSIS

SCOPE

Examinations where it is required to look at the components of an ink or toner. For example, to determine whether two inks or toners are similar, or whether the ink has been subjected to the same ageing process or other treatment. The ability to perform the destructive chemical and physical analyses described here will depend on the availability of these methods at a specific laboratory and the access to the instruments. The document examiners must however have a detailed understanding of these techniques, know when to apply them and be able to put the results of the analyses in a forensic context.

General Knowledge and understanding of ...	Where to learn?	How to test?
History of ink and toner production · Date of introduction of a kind of ink (ball-point, liquid, etc).	Literature[97], casework training	Exam, case assessment
Ageing of inks · Age Estimation Methods · Limitations of these methods · Environmental effects on documents (Light, temperature, humidity etc.)	Literature[98], casework training	Exam, case assessment
Electrophotographic processes · Photocopying, Laser printing, Xerographic process	Courses, Literature[99], casework training	Exam, case assessment

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Chemical composition of inks and toners	Literature[100], casework training	Exam, case assessment

97 R.H. Leach, R.J. Pierce, “The Printing Ink Manual”, Blueprint 1993, ISBN 0-948905-81-6

98 See unit 10

99 A.S.Diamon, D.S. Weiss, “Handbook of Imaging Materials”, Marcel Dekker, Inc. 2002, ISBN; 0-8247-8903-2
J.A.G. Drake, “Chemical Technology in Printing and Imaging Systems”, The Royal Society of Chemistry 1993, ISBN: 0-85186-655-7
P. Gregory, “Chemistry and Technology of Printing and Imaging Systems”, Blackie Academic & Professional 1996, ISBN: 0-7514-0238-9

100 R.H. Leach, R.J. Pierce, “The Printing Ink Manual”, Blueprint 1993, ISBN 0-948905-81-6
A.S.Diamon, D.S. Weiss, “Handbook of Imaging Materials”, Marcel Dekker, Inc. 2002, ISBN; 0-8247-8903-2
J.A.G. Drake, “Chemical Technology in Printing and Imaging Systems”, The Royal Society of Chemistry 1993, ISBN: 0-85186-655-7

Detailed knowledge and understanding of ...	Where to learn?	How to test?
· Chemical composition of ink and toner in general (dyes, solvents, resins etc.) · Influence of substrate, line thickness, chemical, environmental conditions and ageing on the results of the optical and analytical ink examination.		
Recognition of inks and toner · Recognition of the different writing instruments · Discrimination of toner from ink.	Literature[101], casework training	Exam, case assessment
Non destructive examination method	Literature[102], casework training, training courses	Exam, case assessment

P. Gregory, "Chemistry and Technology of Printing and Imaging Systems", Blackie Academic & Professional 1996, ISBN: 0-7514-0238-9

101 J.S. Kelly, B.S. Lindblom, "Scientific Examination of Questioned Documents, second edition", CRC Press 2006, ISBN: 9780849320446

102 J. E. Costain, G. W. Lewis, "A Practical Guide to Infrared Luminescence Applied to Questioned Document Problems", Journal of Police Science and Administration 1 (1973) pp. 209-218

M. Ellen, K. E. Creer, "Infrared Luminescence In The Examination Of Documents", Journal Of The Forensic Science Society, Vol. 10 (1970), Pp.159-164

Sensi. C. A. and Cantu, A. A., "Infrared Luminescence: Is It a Valid Method to Differentiate Among Inks", Journal of Forensic Sciences, Vol. 27, No. 1. Jan. 1982, pp. 196-199.

Cantu, A. A. and Prough, R. S., "Some Spectral Observations of Infrared Luminescence," Journal of Forensic Sciences, JFSCA, Vol. 33, No, 3, May 1988, pp. 638-647.

U. Seipp, "Applications of UV/VIS - Microspectrophotometry and Microspectrofluorimetry in Document Examination," International Journal of Forensic Document Examiners, Vol. 3, No. 1, Jan/Mar 1997, pp.14-30.

R. M. Seifar, J. M. Verheul, F. Ariese, U. A. Th. Brinkman and C. Gooijer, "Applicability of surface-enhanced resonance Raman scattering for the direct discrimination of ballpoint pen inks" , Analyst, 2001, 126, 1418-1422

T. Andermann, "Raman Spectroscopy Of Ink On Paper", Problems Of Forensic Sciences, Vol. Xlvi, 2001, 335-344

P.C. White, "In situ Surface Enhanced Resonance Raman Scattering (SERRS) spectroscopy of biro inks - long term stability of colloid treated samples", Science and Justice, Vol. 43 No.3 (2003) 149 – 152

J. ZieUba-Palus, M. Kunicki, "Application of the micro-FTIR spectroscopy, Raman spectroscopy and XRF method examination of inks", Forensic Science International 158 (2006) 164–172

Andrasko, J. Microreflectance FTIR, techniques applied to materials encountered in forensic examination of documents. Journal of Forensic Sciences. Vol. 41, No. 5, 1996, 812-823.

Wang J, Luo G, Sun S, Wang Z, Wang Y. "Tic analysis of bulk blue ballpoint pen ink by FTIR spectrometry", Journal of Forensic Sciences Vol. 46. No. 5, 2001, 1093-1097

I.R. Tebbett, "Chromatographic analysis of inks for forensic science applications", Forensic Science Review Voi. 3,1991, pp. 71.

V.N. Aginsky, "Using TLC and GC-MS to Determine Whether Inks Came from the Same Manufacturing Batch", Journal of the American Society of Questioned Document Examiners Vol 9, No.1, 2006, pp. 19.

J. A. Tappolet, "The High-Performance Thin Layer Chromatography (Hptlc). Its Application To The Examination Of Writing Inks", Forensic Science International, 22 (1983) pp. 99-109

J. H. Buegler, H. Buchner and A. Dallmayer, "Characterization of Ballpoint Pen Inks by Thermal Desorption and Gas Chromatography-Mass Spectrometry", Journal of Forensic Sciences, Vol. 50, No. 5, Sept. 2005, pp.1

Tebbett. I. R.. Chen. C, Fitzgerald. M., and Olson, L., "The Use of HPLC with Multiwavelength Detection for the Differentiation of Non Ball Pen Inks," Journal of Forensic Sciences, Vol. 37. No. 4, July 1992. pp. 1149-1157.

Andrasko J. "HPLC analysis of ballpoint pen inks stored at different light conditions", Journal of Forensic Sciences, Vol. 46, No. 1, 2001, pp. 21–30.

X. Xu, J.A. de Koeijer, J.J.M. de Moel and H. Logtenberg, "Ink Analysis for Forensic Science Applications by Micellar Electrokinetic Capillary Chromatography with Photo-diode Array
Detection", International Journal of Forensic Document Examiners, Vol. 3, No. 3, July/Sept 1997, pp. 240-260.

Vogt C. Becker A, Vogl J. "Investigation of ballpoint pen inks by capillary electrophoresis (CE) with UV/Vis absorbance and laser induced fluorescence detection and particle induced x-ray emission (PIXE)", Journal of Forensic Sciences Vol.44, No. 4, 1999, pp. 819-831.

S. J. Pachuta, J. S. Staral, "Nondestructive Analysis of Colorants on Paper by Time-of-Flight Secondary Ion Mass Spectrometry", Analytical Chemistry, Vol. 66, 1994, pp. 276-284

T.P. Wampler And E J . Levy, "Pyrolysis GC in the Analysis of Inks and Papers", LC'GC Vol. •4, No. 11, pp. 1112

Detailed knowledge and understanding of ...	Where to learn?	How to test?
· Microscopic and physical examination · Filtered light examination o Luminescence behaviour (Be aware of the influence of substrate (and background), line thickness, chemical, environmental conditions and ageing on the results of the optical and analytical ink examination) o IR Reflection/Absorbance behaviour o Recognition of the chemical erasure (appearance of chemical agents and or residual impressions) · Spectroscopic methods o Microspectrophotometry (Reflectance and Transmittance) o (Surface Enhanced Resonance) Raman Spectroscopy (SERS and SERRS) o Fourier Transform Infrared spectroscopy (FTIR) Destructive examination methods · Extraction methods · Separation methods o Chromatographic techniques (GC, TLC, HPLC) o Capillary Electrophoresis techniques	by equipment Manufacturers	

B. M. Trzcinska, "Classification of Black Powder Toners on the Basis of Integrated Analytical Information Provided by Fourier Transform Infrared Spectrometry and X-Ray Fluorescence Spectrometry", Journal of Forensic Sciences, Vol. 51, No. 4, July 2006, pp. 919
Brandi, J., B. James and Gutowski, S.J., "Differentiation and Classification of Photocopier Toners," International Journal of Forensic Document Examiners, Vol. 3, No. 4, Oct/Dec 1997, pp. 324-343.
J. D. Wilson, G. M. LaPorte, A. A. Cantu, "Differentiation of Black Gel Inks Using Optical and Chemical Techniques", Journal of Forensic Science, Mar. 2004, Vol. 49, No. 2, pp. 1-7,
A. Kher, M. Mulholland, E. Green, B. Reedy, "Forensic Classification of Ballpoint Pen Inks Using High Performance Liquid Chromatography and Infrared Spectroscopy with Principal
Components Analysis and Linear Discriminant Analysis", Vibrational Spectroscopy 40 (2006), pp. 270–277,
W. D. Mazzella, A. Matheiu, p. Buzzini "Micro-Raman Spectroscopy of Color Inkjet Printed Documents", Journal of the American Societty of Questioned Document Examiners", Vol. 9, No. 1, 2006, pp. 1-8,
J. M. Egan, J. D. Brewer, K. A. Hagan, C. L. Strelko "Capillary Electrophoresis of Ballpoint Pen Inks", Journal of the American Societty of Questioned Document Examiners", Vol. 9, No. 1, 2006, pp.37-45.
Relevant EDEWG (Toner Examination and Ink Analysis by TLC) and ASTM methods.

Detailed knowledge and understanding of ...	Where to learn?	How to test?
○ Hyphenated Techniques (e.g. Pyrolysis-Gas Chromatography-Mass Spectrometry (Pyr.-GC/MS)		
· Elemental methods (inorganic analysis)		
○ Scanning Electron Microscopy / Energy Dispersive X-Ray Fluorescence (SEM/EDX)		
○ μ-X-Ray Fluorescence Analysis		
○ Laser Ablation Inductive Coupled Plasma Mass Spectrometry (LA-ICPMS)		

Able to	Where to learn?	How to test?
Apply above knowledge to casework	See above	See above
Recognise writing instruments and electrostatic printing techniques by their physical characteristics	Casework training	Exam, case assessment
Examine ink and toner using non-destructive techniques	Casework training	Exam, case assessment
Interpret evidence from chemical analysis of ink and toner in a forensic context	Casework training	Exam, case assessment
Perform the destructive chemical and physical analyses of ink and toner used by the document section of a specific laboratory	Casework training	Exam, case assessment
Prepare comprehensive reports outlining your examinations and results	Casework training	Exam, case assessment

UNIT 10 DATING OF DOCUMENTS

SCOPE

All examinations where it is desired to estimate the age of a document or to check if a document was written on the alleged date. The ability to perform the destructive chemical and physical analyses described here will depend on the availability of these methods at a specific laboratory and the access to the instruments. The Document Examiners must however have a detailed understanding of these techniques, know when to apply them and be able to put the results of the analyses in a forensic context.

General Knowledge and understanding of ...	Where to learn?	How to test?
Knowledge described in other units · Unit [3] Paper Examination · Unit [9] Ink and Toner Analysis	See relevant units	Exam, case assessment

Detailed knowledge and understanding of ...	Where to learn?	How to test?
History of ink production · Introduction of different ink/pen types · Introduction of different additives · Addition of chemical markers to inks	Literature[103], casework training	Exam, case assessment
History of paper production · Introduction of different paper types · Introduction of different additives · Watermark collections	Literature[104], casework training	Exam, case assessment

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103 Apply above knowledge to casework See above See above
Assess the possibilities for age determination of a document and determine the correct examination sequence
Casework training Exam, case assessment
Determine the reliability of the applied methods Casework training Exam, case assessment
Put the results of the examination in a forensic context Casework training Exam, case assessment
Prepare comprehensive reports outlining your examinations and results Casework training Exam, case assessment
104 See Unit 3.

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Ageing process of ink and paper · Natural ageing · Light exposure · Storage conditions	Literature[105], casework training	Exam, case assessment
History of typewriters, printers, faxes and copiers · Introduction of different instruments · Introduction of different fonts	Literature[106], casework training	Exam, case assessment
Artificial ageing techniques · Light exposure · Heat exposure · Exposure to chemicals	Literature[107], casework training	Exam, case assessment
Examination methods	Literature[108], casework training	Exam, case assessment

105 C. Weyerman, “Mass Spectrometric Investigation Of The Aging Processes Of Ballpoint Ink For The Examination Of Questioned Documents”, Dissertation, Justus-Liebig-University Giessen, sep.
2005
Andrasko J. “Changes in composition of ballpoint pen inks on aging in darkness”, Journal of Forensic Sciences Vol 47, No.2, 2001, pp.324–327.
Andrasko J. HPLC anal) sis of ballpoint pen inks stored at different light conditions. Journal of Forensic Sciences Vol. 46, No.1, 2001, pp. 21-30.
J. Andrasko and M. Kunicki “Inhomogeneity and Aging of Ballpoint Pen Inks Inside of Pen Cartridges”, Journal of Forensic Sciences, , Vol. 50, No. 3, May 2005, pp. 1
C. Weyermann,* D. Kirsch, C. Costa-Vera and B. Spengler, “Photofading of Ballpoint Dyes Studied on Paper by LDI and MALDI MS”, Journal of the American Society of Mass Spectrometry Vol.
17, 2006, pp. 297–306
H.R Hamed, N.M. Safey El-Din, S.A. El-Laithy, O.Y. Mansour and M.W. Sabaa, "Effect of Accelerated Fading on the Stability of Inks Marked on Different Types of Papers" International Journal
of Forensic Document Examiners, Vol. 3, No. 3, July/Sept 1997, pp. 229-236.
S Lociciro*, L Dujourdy, W Mazzella, P Margot and E Lock, “Dynamic of the ageing of ballpoint pen inks: quantification of phenoxyethanol by GC-MS”, Science and justice, Vol. 44, No.3
(2004) pp. 165 – 171

106 H. Kipphan, “ Handbook of Print Media, Technologies and Production Methods”, Springer Verlag 2001, ISBN: 3-540-67326-1
E. Webster, “Print Unchained – Fifty Years of Digital Printing, 1950-2000 and Beyond, A Saga of Invention and Enterprise” DRA of Vermont, Inc. 2000, ISBN: 0-9702617-0-5
J.S. Kelly, B.S. Lindblom, “Scientific Examination of Questioned Documents, second edition”, CRC Press 2006, ISBN: 9780849320446

107 R. L.. Feller, “Accelerated Aging, Photochemical and Thermal Aspects”, The J. Paul Getty Trust, 1994, ISBN 0-89236-125-5
M. E. Vos, S. J. Strach, and P. D. Westwood, “The Effect of Sunlight and Fluorescent Tube Light on Inks and Papers”, Journal of the American Society of Questioned Document Examiners Vol 1, No.1, 1998, pp. 17.

108 R.L. Brunelle, R.W. Reed, “Forensic Examination of Inks and Paper”, Charles C Thomas Publisher, 1984, ISBN 0-398-04935-1
R.L. Brunelle, K.R. Crawford, “Advances in the Forensic Analysis and Dating of Writing Ink”, Charles C Thomas Publisher, 2004, ISBN 0-398-07346-5Cantu, Antonio A., "A Sketch Of Analytical Methods For Document Dating Part 1. The Static Approach: Determining Age Independent Analytical Profiles," International Journal of Forensic Document Examiners, Vol. 1, No. 1, 1995, pp. 40-51.

Detailed knowledge and understanding of ...	Where to learn?	How to test?
· Age estimation methods o Relative ageing o Induced ageing o Date of production from ink database o Solvent extraction techniques o Chromatographic techniques to determine solvent content such as (GC/MS, HPLC) o Component degradation techniques · Limitations of these methods o Methods, monitoring time-variable properties of inks or other materials of documents are still in controversial discussion within the scientific forensic community. Each method should be properly evaluated before using it in casework.		

Able to	Where to learn?	How to test?
Apply above knowledge to casework	See above	See above
Assess the possibilities for age determination of a document and determine the correct examination sequence	Casework training	Exam, case assessment
Determine the reliability of the applied methods	Casework training	Exam, case assessment
Put the results of the examination in a forensic context	Casework training	Exam, case assessment
Prepare comprehensive reports outlining your examinations and results	Casework training	Exam, case assessment

Cantu. A.A., "A Sketch of Analytical Method for Document Dating Part II. The Dynamic Approach Determining Age Dependent Analytical Profiles,," International Journal of Forensic Document Examiners. Vol. 2, No. 3. July/Sept 1996. pp. 192-208.
C. Weyerman, "Mass Spectrometric Investigation Of The Aging Processes Of Ballpoint Ink For The Examination Of Questioned Documents", Dissertation, Justus-Liebig-University Giessen, sep. 2005
Stewart, L. F. and Fortunato. S. L.. "Distinguishing Between Relative Ink Age Determinations and the Accelerated Aging Technique," International Journal of Forensic Document Examiners, Vol. 2. No. 1, Jan/Mar 1996, pp. 10-15
J. H. Bugler, H. Buchner and A. Dallmayer, "Age Determination of Ballpoint Pen Ink by Thermal Desorption and Gas Chromatography-Mass Spectrometry", Journal of Forensic Sciences Vol. 53, No.4, 2008, pp. ??.
C. Berger-Karin, U. Hendriks and J. Geyer-Lippman, "Comparison of Natural and Artificial Agening of Ballpoint inks", Journal of Forensic Sciences Vol. 53, No.4, 2008, pp. 989-992.

UNIT 11 OPENED AND RESEALED ENVELOPES

SCOPE

Any examination where it is alleged that a seal on a paper item, particularly an envelope, has been opened, and then subsequently resealed.

General Knowledge and understanding of ...	Where to learn?	How to test?
Paper and envelope manufacture	Literature[109], casework training	Exam, case assessment
Knowledge described in other units	See relevant units	Exam, case assessment
· Unit [3] Paper Examination		
· Unit [12] Damaged Documents		

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Sealing techniques	Literature[110], casework training	Exam, case assessment
· Types of glue		
Signing over a flap	Casework training	Exam, case assessment
Addition of glue	Casework training	Exam, case assessment
· Detection		
· Analysis		
Examination methods	Casework training	Exam, case assessment
· Microscopic examination		
o Fibre displacement		
o Mechanical fits		
· Indented impressions of location of contents		
o Oblique Light		
o Electrostatic detection		

109 See literature in unit 3.

110 No specific literature available

Detailed knowledge and understanding of ...	Where to learn?	How to test?
· Determining the contents without opening		
o Transmittance techniques		
*Scanning with transmitted light		
*Solvents to make paper translucent		
*X-Ray transmission		
· Opening and resealing an envelope		
o Fibre transfer		
o Tearing		
o Steaming		
o Opening a self-seal envelope		
*Chemicals applied		
*Freezing		
o Resealing an envelope		
Preservation of evidence for further examination e.g. Fingerprints, DNA etc.	Casework training	Case assessment

Able to	Where to learn?	How to test?
Apply above knowledge to casework	See above	See above
Determine if an envelope has been opened and resealed	Casework training	Exam, case assessment
Determine the contents of an envelope without opening it	Casework training	Exam, case assessment
Prepare comprehensive reports outlining your examinations and results	Casework training	Exam, case assessment

UNIT 12 DAMAGED DOCUMENTS

SCOPE

All examinations to determine the contents of documents which have been damaged by water, fire, heat, mechanical tearing or shredding, biological action etc.

Deterrence of further deterioration.

General Knowledge and understanding of ...	Where to learn?	How to test?
Effects of: · burning on documents · exposure to solvents, water etc on documents	Literature, casework training	Exam, case assessment
Techniques used in the storage and restoration of documents	Literature[111], casework training	Exam, case assessment

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Handling charred documents · Immobilisation · Application of lacquer or another stabilising agent	Literature[112], casework training	Exam, case assessment

111 ASTM, Standard Practice for Receiving, Documenting, Storing and Retrieving Evidences in a Forensic Science Laboratory, Designation: E 1492-92, 1992, www.astm.org.Annual Book of ASTM Standards;
Harrison Wilson R., Suspect Documents, Frederick A. Praeger, New York, 1958;
J.S. Kelly, B.S. Lindblom, "Scientific Examination of Questioned Documents, second edition", CRC Press 2006, ISBN: 9780849320446
Mitchell C. Ainsworth, Documents and their scientific Examination, Charles Griffin & Company Limited, London, 1935;
Osborn Albert S., Questioned Documents, Boyd Printing Co., Albany, NY, Second Edition, 1929;
Baxter Peter G., The Use and Abuse of Documents, Vol.9, No.1, January 1969, pp. 39-44 Medicine, Science and The Law;
Ellen David, The Scientific Examination of Documents: methods and techniques, Ellis Horwood Limited, Chichester, West Sussex, England, 1989;
Hilton Ordway, The Care and Preservation of Documents in Criminal Investigation, Vol. 31, No. 1, May –June 1940, pp.103-110 Journal of criminal Law and Police Review;

112 Bartha and Duxbury A. and N.W., Restortion and Preservation of Charred Documents, Vol. 1,No. 1, March 1968, pp.2-5 Canadian Society of Forensic Science Journal;
Black David A., Decipherment of Charred Documents, Vol. 38, No. 5, 1948, pp. 542-546 Journal of Criminal Law an s Criminology;
Carney Brian B., A Charred Document Case Made Easy, Vol. 2, No. 4, October/December 1996, pp. 347-353 International Journal of Forensic Documents Examiners;
Doud Donald, Decipherment of Altered and Charred Documents, May 10 & 11, 1956, pp. 39-47 Royal Canadian Mounted Police, Seminar No. 4, The Examination of Questioned Documents;
Doud Donald, Charred Documents, Their Handling and Deciphement, Vol. 43, No. 6, March-April, pp. 812-826 Journal of Criminal Law, Criminology and Police Science;
Tyrrell John F., The Decipherment of Charred Documents, Vol. 30, No. 2, July-August 1939, pp. 236-242 Journal Of Criminal Law and Criminology;
Doud Donald, Report On The Reconstruction of two Time Payment Ledgers damaged by Fire and Water, Vol. 50, No.3, September-October 1959, pp. 291-295 Journal of Criminal Law , Criminology and Police Science;

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Handling wet documents · Freeze drying · Deterrence of further deterioration o Controlling the ph of wet documents o Killing bacteria and fungi (e.g. with gamma radiation)	Literature[113], casework training	Exam, case assessment
Heat sensitive papers	Literature, casework training	Exam, case assessment
Examination methods · Microscopic and physical examination · Filtered light examination o Charred and wet documents · Mechanical fits o Torn, cut or shredded documents Knowledge described in other units: · Unit [3] Paper Examination · Unit [5] Printing Technology · Unit [10] Dating of Documents	Literature[114], casework training	Exam, case assessment

Able to	Where to learn?	How to test?
Apply above knowledge to casework	See above	See above

113 Taylor Linda R., The Restoration and Identification of Water –Soaked Documents: A Case Study, Vol. 31, no. 3, July 1986, pp 1113-1118 Journal of Forensic Sciences;
Hilton Ordway, The Care and Preservation of Documents in Criminal Investigation, Vol. 31, No. 1, May –June 1940, pp.103-110 Journal of criminal Law and Police Review;

114 Peace Leslie L., The Examination of Torn and Perforated Documents, Vol. 15, No. ¾, September/December 1982, pp. 116-132 Canadian Society of Forensic Science Journal;
Schuetzner and Cornelia Ellen Mulcrone and Kim, The Shredded Paper Puzzle: The Reconstruction of Shredded Documents, Vol. 4, No. 3, July/September 1998, pp. 273-279 International Journal of Forensic Document Examiners;
Purtell David J., The Identification of Paper Cutting Knives and Paper Cutters, Vol. 44, No. 2, July-August 1953, pp. 262-268 Journal of Criminal Law, Criminology and Police Service;

Able to	Where to learn?	How to test?
Handle and examine charred and wet documents	Literature, casework training	Exam, case assessment
Handle and examine documents on heat sensitive paper	Literature, casework training	Exam, case assessment
Examine torn, cut or shredded documents for physical fits	Literature, casework training	Exam, case assessment
Prepare comprehensive reports outlining your examinations and results	Casework training	Exam, case assessment

UNIT 13 ANONYMOUS LETTERS

SCOPE

All document examinations performed to determine the source of an anonymous letter.

General Knowledge and understanding of ...	Where to learn?	How to test?
Securing digital evidence	Casework training	Exam, case assessment
How the postal services operate	Visit to postal services, casework training	Exam, case assessment
Handwriting characteristics	Literature[115], casework training	
Knowledge described in other units	See other units	Exam, case assessment
Unit [2] Alterations, obliterations, non-destructive ink comparison		
Unit [3] Paper examination		
Unit [4] Typewriting		
Unit [5] Reproduction and printing technology		
Unit [9] Ink and toner analysis		
Unit [11] Opening/resealing envelopes		
Unit [12] Damaged documents		

Detailed knowledge and understanding of ...	Where to learn?	How to test?
Contamination of DNA evidence	Casework training	Exam, case assessment

115 Casey-Owens, M., The Anonymous Letter Writer—A Psychological Profile? Journal of Forensic Science, Vol. 29, Issue 3,(July 1984);
Conway James V.P., Personal and Personality Characteristics in Anonymous Letters, Vol. 4, NO.4, January 1959, pp. 18-33 Journal of Forensic Sciences;
Harris Joel S., Determining Nationality from Written Speech, Vol. 2, No.4, October/December 1996, pp.300-325 International Journal of Forensic Document Examiners;
Moon Harold W., A Survey of Handwriting Styles by Geographic Location, Vol. 22, No.4, October 1977, pp. 827-834 Journal of Forensic Sciences;
Muehlberger Robert J., Identifying Simulations: Practical Considerations, Vol. 35, No.2, March 1990, pp. 368-374 Journal of Forensic Sciences;
Robert Saudek, Anonymous letters : a study in crime and handwriting, New York : AMS Press, [©1976];
Stangohr Gordon R., Comments on the Determination of Nationality from Handwriting, Vol. 16, No.3, July 1971, pp. 343-367 Journal of Forensic Sciences;

Detailed knowledge and understanding of ...	**Where to learn?**	**How to test?**
Sequence of multidisciplinary examinations	Literature[116], casework training	Exam, case assessment
Production processes of envelopes	Literature[117], casework training	Exam, case assessment
Production processes of paper	Literature[118], casework training	Exam, case assessment
Paper comparison	Literature[119], casework training	Exam, case assessment
Comparison of other items	Literature[120], casework training	
Recognition of writing and printing techniques	Literature[121], casework training	Exam, case assessment
Ink and toner analysis	Literature[122], casework training	Exam, case assessment
Analysis of printed and typewritten documents	Literature[123], casework training	Exam, case assessment

Able to	**Where to learn?**	**How to test?**
Apply above knowledge to casework	See above	See above
Coordinate the multidisciplinary examination of an anonymous letter	Casework training	Exam, case assessment

116 Horan James J., Processing Letters from Terrorists and Other Criminals, Vol.5, No.2, June 1977, pp. 145-147 Journal of Police Science and Administration;
Quirke, A. J.,Forged Anonymous and Suspect Documents, George Allen & Uniwin, Ltd., London, 1930;

117 Bertocchi Michael P., Envelope Association Through manufacturing Characteristics, Vol. 22, no. 4, October 1977, pp. 815-818 Journal of forensic sciences;
W.D. Mazzella, F Taroni, “A simple logical approach to questioned envelopes Examination”, Science & justice, Vol. 45 No.1 (2005) 1 – 4

118 See unit 3

119 See unit 3

120 Casey Owens, M., The Comparison of Round-Hole Perforations of Postage Stamps Journal of Forensic Science, Vol. 4, Issue 4,(October 1985);
Mason and Grose Julien J. and Wesley.P. , The Individuality of Toolmarks Produced by a Label Maker used to Write Extortion Notes, Vol. 32, No.1, January 1987, pp. 137-147 Journal of Forensic Sciences;
Purtell and Casey David J. and Maureen A., Paper Tapes and Labels Encountered in Document Examination, Vol. 11, No. 4, October 1966, pp. 496-506 Journal of Forensic Sciences;
Purtell David J., The Identification of Paper Cutting Knives and Paper Cutters, Vol. 44, No. 2, July-August 1953, pp. 262-268 Journal of Criminal Law, Criminology and Police Service;

121 See units 2, 5 and 9

122 See unit 9

123 See units 4 and 5.

Able to	Where to learn?	How to test?
Perform all necessary examinations to determine a possible source	Casework training	Exam, case assessment
Compare anonymous letters to determine a common source	Casework training	Exam, case assessment
Compare anonymous letters to writing or printing instruments to determine a possible source	Casework training	Exam, case assessment
Secure micro-traces of evidence	Casework training	Exam, case assessment
Secure saliva traces for DNA analysis	Casework training	Exam, case assessment
Secure other types of document evidence for later comparison	Casework training	Exam, case assessment
Prepare comprehensive reports outlining your examinations and results	Casework training	Exam, case assessment

APPENDIX 2 – OVERVIEW PROCEDURE FOR EXAMINATION OF SECURITY DOCUMENTS

1. INTRODUCTION

Security documents are unique in that they are designed to allow at any time of their life cycle verification of their authenticity and validity as documents issued by the competent authority of a country or organization. Security documents have a high intrinsic value as they are designed to identify people and goods, to legitimise property and rights or to have a direct or indirect fiduciary value; therefore they have always been a preferable target of forgery and counterfeiting.

The forgery and counterfeiting of security documents are present in all cases of serious crime – economic and financial crime, trafficking and smuggling of human beings, drug trafficking, illegal transport of weapons or vehicles, money laundering, corruption and terrorism. Forensic document examiners are often called upon to analyse these documents, in order to determine if the questioned documents are authentic or counterfeit or if they have been falsified in some way.

Depending on the type of document and the client's request, the examination of a security document may require multiple examination procedures such as macroscopic and microscopic examination, inspection under special lighting conditions, physical examination and chemical analysis. Some security features may only be detected with the use of specific equipment, such as decoding lens etc.

2. SCOPE

This procedure covers the analysis of security documents in order to determine if they are authentic, counterfeit and/or falsified. The procedure applies to all types of security documents, independent of the substrate and origin, such as banknotes, ID documents, travel documents, securities, vehicle registration documents, driving licenses, payment cards, etc. Commercial and other types of documents (e.g. authentication labels, packaging) whose design in some way meets one of the security standards mentioned below may also be analysed according to this procedure.

The procedure also covers the examination of counterfeit security documents in order to determine how they were produced and to classify them according to their respective class characteristics.

Furthermore, it covers the examination of seized materials and equipment which was used or could have been, or was intended to be used in the production of counterfeit or forged documents.

Except for corroborating the variable information printed on the document, this procedure does not apply to the analysis of data stored on magnetic strips or chips that are included in some security documents, nor to the evaluation of the chip's integrity.

3. PRINCIPLES

The purpose of the examination is to determine the authenticity of a questioned document and to analyse its consistency or inconsistency with respect to a suitable specimen and / or with relevant information obtained from a trustworthy source, while taking into account the substrate(s), the printing techniques, the personalisation techniques, the various security features present in the document and the finishing methods.

The security level of a document varies depending on the intended use and expected lifespan. It may be high (e.g. banknotes or ID and travel documents), medium (e.g. vehicle registration documents) or low (e.g. lottery tickets, tickets for events or other short lifespan documents). In order to produce documents with the required security levels, controlled raw materials are used which are sourced from a restricted number of suppliers and sometimes are even exclusive to one. Special printing techniques and inks are used which are restricted to authorized printing works and difficult to imitate. Last but not least, additional security features are included into the document to prevent forgery and counterfeiting and / or to assist in the detection of such forgery or counterfeiting. These security features can be present in the raw materials, in the design and printing techniques and / or they can be applied to the documents after printing. Depending on their characteristics, they act as first, second, third or fourth level security features.

First level security features are designed to be easily identified without instruments, using only the sensorial functions of sight, touch and hearing in a natural environment. Second level security features may be identified using simple equipment like hand held magnifiers or a UV-light source. Third level security features are conceived to be automatically verified by means of adequate readers. Finally, fourth level security features are intended to be verified at forensic laboratories, using more specific equipment.

In many countries / organisations, security features are classified in three levels: First level security elements are detected without any equipment (as above). Second level security elements are detected with the aid of equipment. Third level security elements are secret. They can be detected by the naked eye (e.g. designed defects in printed characters), by the aid of equipment (e.g. IR-luminescent particles in the paper) or by physical / chemical analysis (e.g. tracers within the security ink). Thus, the definition of “third level” is that the knowledge of such elements is restricted to few people, and even these persons are not public.

Due to the very large number of security documents used all over the world and to the difficulties in (sometimes) obtaining genuine specimens, no Document Examination laboratory has a complete reference collection of documents that may be sent in for analysis. So, in several cases the examination of a security document will be based on the evaluation of the technological development level of the questioned document considering technology available, the country of origin and the international requirements for certain types of documents. This requires the expert to have a solid knowledge on these matters and a good understanding of their possibilities, limitations and interactions.

The principle of comparing counterfeits to determine if they have a common origin is to examine the questioned document for class characteristics and record the similarities and differences.

To determine if seized material and equipment have possibly been used in the production of questioned documents, it has to be evaluated, if their application is technically viable to produce such falsifications. In a second step, the output of the equipment and / or the material is compared with the questioned falsifications.

The examination techniques used to examine the document are indicated below. Depending on the characteristics of the questioned security document, the examiner will decide which tests need to be undertaken and in what order. This list includes the most frequently used examination techniques though occasionally the expert may need to perform other examinations, like measurements of thickness, bright field / dark field microscopy, microspectrophotometry, Raman spectroscopy, FTIR spectroscopy, X-ray fluorescence, X-ray transmittance, chromatographic techniques (GC, TLC, HPLC), etc.:

- Visual examination under natural lighting conditions (direct and transmitted light)
- Optical examination with a magnifying glass or stereo microscope with various types of lighting (most commonly direct light, oblique light, transmitted light, retro-reflected light)
- Examination under long- and short-wave UV-light
- Examination with a magnetic ink detector
- Examination of VIS and (N)IR luminescence properties
- Examination of NIR absorption and reflection
- Examination with decoders

4. GLOSSARY

Following is the list of words and phrases to be understood by the examiner of Security Documents.

Anti-stokes ink - security ink that fluoresces in a shorter wavelength band than that of the exciting light

Binding technique - process of combining single sheets to form a book, booklet or brochure

Camouflage documents - documents that claim to be issued by countries or organizations that no longer exist or have a new name, e.g. Rhodesia (now Zimbabwe) or British Honduras (now Belize)

Counterfeit - unauthorized copy or reproduction of an authentic security document

Decoder - analogue or digital system that allows the visualisation of scrambled indicia printed hidden on some part of a security document

DOVIDs (Diffractive Optically Variable Image Devices) - security features containing gratings or other microstructures, whose colour changing and kinematic effects or 2D / 3D images result from the diffraction of light on these grating structures; depending on the method used to create the gratings or microstructures, different image resolutions, brightness and animation capabilities may be obtained

Forgery - unauthorized alteration of some part of a document

Falsification - Counterfeit or Forgery

Fantasy document - a document that bears the names of an imaginary state or organization e.g. World Service Authority Passport, IADC (International Automobile Driver's Company Inc.) etc.

Fluorescent overprint - overprint that is colourless under normal light but fluoresces under UV light

Fraudulently issued document - authentic blank (usually stolen) document, which was personalized by an unauthorized person

Fugitive ink - soluble ink which dissolves in certain solvents or water, causing parts of the security printing to disappear or bleach when exposed to these solvents

Ghost image - second facial image of the document bearer that may be applied by the same printing process as the primary image, or by a different process, e.g. fluorescent overprint or laser perforation

Identification / travel document - security document issued by a competent authority, which allows the verification / identification of the bearer and the circulation within a certain geopolitical space

Image perf - laser perforation ghost image

Iridescent security features - those showing shiny, pearl lustre-like effect with changes in colour according to the angle of viewing

Laser engraving - engraving of pictures or texts in laminates or cards by means of a laser

Latent image - image produced using intaglio printing that can be perceived by observing the area that contains it obliquely to a strong light source

Metameric ink - pairs of chemically different security inks which show the same colour under normal light, but different behaviour when viewed through a filter, usually a red filter

Miniprint, microprint, nanoprint - lines or motifs made up of very small characters that are barely perceptible to the eye; while the first two may be seen under low magnification, nanoprint requires the use of high magnification to be seen

MRZ (Machine Readable Zone) - letters and sequence of alphanumeric characters present in identification and travel documents, containing data such as type of the document, name of bearer, expiry date and check digit (number which is calculated by the aid of a special algorithm applied on the precedent characters). MRZ can be read and checked by document readers to support the inspection of these documents

Ovd (optically variable device) - security features which show different information depending on the viewing angle and/or lighting conditions

OVI (Optically Variable Ink) - printing ink containing special pigments which show strong variations in colour depending on the viewing angle

Planchettes - Small discs often of synthetic materials, that are added as security feature to the paper during the manufacturing process; they may be coloured, iridescent and/or UV reactive

Pseudo document - a document having the appearance of an official document but not issued by a legal, authority of a state recognized under international law, e.g. fantasy documents or camouflage documents

Retro-reflective security feature - invisible image incorporated into laminates and rendered visible under coaxial lighting conditions

Scrambled indicia - visible image that is printed encoded within other images rendering them invisible to the naked eye and which can only be detected by the use of an adequate decoder

Security document - document whose structure includes various security features in order to allow the verification of its authenticity and validity, and to prevent / reveal its counterfeiting or falsification

Security feature - material and / or analogue or digital device included in a security document to prevent and / or render evident its counterfeiting, falsification or manipulation

Security thread - stripe (plastic, metallic or of another material) incorporated into the substrate (usually paper) during the manufacturing process to serve as an additional security feature

See-through register - image partially printed on both sides of a substrate in accurate front-to-back register, showing the complete motif when viewed with transmitted light

Substrate - material into / onto which all elements defined during the conception of a security document are embedded / printed, including the individual data

Tank tracking - method of securing a conventionally fixed photo of bearer applied with a hand press in the form of a pattern of lines; between the lines there are often perforated holes

Watermark - text or image resulting from varying densities of the paper fibres / thickness of the paper; it is produced during the paper manufacture by transfer of a projecting design from a mould or roll onto the paper substrate and can be observed under transmitted (and sided) light.

5. CROSS REFERENCES

- Recognition of Printing Techniques
- Application of Luminescence to the Examination of Documents
- NIR Absorption and Reflection Examination of Documents
- Non-destructive Paper Examination
- Examination of Alterations
- Stamps and Stamp Impressions
- Editions Keesing Publishers, “Counterfeits & Forgeries
- Editions Keesing Publishers, “Passport Handbook”
- Editions Keesing Publishers, “Documentchecker” (http://www.documentchecker.com/)
- New Zealand Police Document Examination Section, “Printing Processes Manual”
- EDISON Database
- DISCS Database
- FADO (iFADO) - EU False and Authentic Documents Online
- PRADO - The Council of the European Union, Public Register of Authentic Identity and Travel Documents Online
- Hauff Verlag, “Führerscheine der Welt“
- MRI Bankers’Guide

6. PRESERVATION AND HANDLING OF ITEMS

Occasionally, security documents bear evidence requiring them to be further analysed by other sections of a laboratory. If necessary, these evidence traces (e.g. DNA, fingerprints) should be carefully secured and adequately preserved for further analyses. Where chemical or destructive processes are needed, a copy or photograph of the security document must be taken in advance. The expert will also determine what examinations need to be performed prior to the removal of traces or the development of latent prints.

If biological examinations are necessary, the documents must be stored in paper envelopes or bags – never in plastic covers – and preserved in the freezer.

Protection of evidence must be taken into account if further examination such as electrostatic detection, latent fingerprint investigation or DNA-analysis are necessary or possible (gloves, mask, prevention from new indentations).

Electrostatic detection must be performed before the examination of latent prints.

7. EQUIPMENT/INSTRUMENTATION/OPERATING CONDITIONS

- Magnifier
- Stereomicroscope with variable lighting (e.g. incident, sided and transmitted light)
- Microscope
- UV light source (254 nm and 366 nm)
- Video-spectral comparator
- Magnetic ink detector
- Decoders
- Retroviewer
- MRZ reader
- Barcode reader
- Magnetic stripe reader
- Chip reader
- Paper scales
- Thickness gauge
- Dark room for UV and luminescence examinations

8. REAGENTS AND MATERIALS

- Tweezers
- Scalpel
- Needle
- Ruler
- Black working surface may be useful
- UV protective glasses
- Organic and inorganic solvents

9. HEALTH AND SAFETY

The usual precautions for luminescence examinations should be observed, namely the use of protective gloves and eyewear when using UV light sources or powerful lasers or Xenon lamps.

Documents may be contaminated by biological (e.g. blood), microbiological (e.g. *fungi*) or chemical (e.g. ninhydrin) residues. Examiners must take the appropriate measures when handling such security documents, namely using gloves, protective clothing, mask and eyewear. Caution must be taken not to risk contamination of equipment and other surfaces by failing to remove gloves before using keyboards, turning lights on/off, etc.

All work surfaces used to examine potentially bio-hazardous documents, should be covered with paper. After the examination these surfaces, the examination equipment and instruments used must be cleaned with a suitable disinfecting solvent e.g. a 10% solution of bleach and a 70% solution of ethanol.

Security documents which have been previously treated with ninhydrin shall be stored in plastic covers and whenever possible examined through this protection. Otherwise suitable protective measures must be taken by the examiner to prevent direct contact with the treated items.

10. PREPARATION AND CALIBRATION OF EQUIPEMT AND REAGENTS

Each piece of equipment should be calibrated if applicable and / or verified according to the maintenance schedule in place.

11. PROCEDURE

Locate a specimen of the questioned security document or, if a specimen is unavailable, consult description on databases (electronic or printed information) and or relevant reference material.

If there is neither a specimen nor a bona fide description or reference material, perform the necessary examinations to evaluate the degree of technological development of the questioned security document. Based on the experts specific knowledge and experience and taking into account the issuance country / organisation, the expert may be able to nonetheless evaluate the authenticity of the document.

Examine the specimen document, reference material and the questioned security document using the same techniques and covering all aspects of the document – physical characteristics (e.g. dimensions, colour, fluorescence, IR-luminescence), substrates, production process technologies, quality of printing (paying special attention to areas of detail), security features, magnetic properties of inks, authentication marks (e.g. stamps, dry stamps), finishing techniques and other details.

Compare the specimen document and reference material to the questioned security document looking for similarities and differences. Bear in mind that some deviations between them may be due to different editions if both exhibits otherwise contain the same production techniques and security devices.

After all examinations have been performed, it may be necessary to check the available databases on documents reported lost or stolen including blank stolen documents (e.g. Interpol, Shengen).

If the client further requests the comparison with other counterfeits or forgeries for the purpose of establishing a common origin, use the same approach as in 11.3. Compare all aspects of the falsifications in terms of materials used, production techniques and common defects. Also consider analysis of individual marks of the printing device.

If applicable, compare seized materials and/or equipment with the counterfeited security documents and/or with existing counterfeit databases to determine if there is a possible common origin. Compare all relevant aspects of the materials, the production techniques and the outputs of seized equipment looking for similarities, differences and common defects.

A list of techniques commonly used for the examination of questioned security documents is provided below. As the type of documents varies, so do the nature and type of counterfeits and falsifications. The listed techniques may not address all circumstances that could be encountered in casework, and some may not be suitable or even necessary in certain cases. The examiner will need to establish which techniques are required for each case and their order of application.

Preliminary examination without instruments and under natural lighting conditions, although hand held magnifier should be used where necessary.

- Evaluation of the type of document and of the nature and condition of its different parts:
  - Preliminary visual inspection – type of Document, Passport, ID card, Licence etc., the type and structure of substrate, one-leaf or multi-leaf document; if applicable: covers, booklet, stickers, stamps, etc.
  - Verification of the integrity of the document – part(s) missing or not, total number of pages and alignment if applicable, colour, evidence of tampering (e.g. fugitive inks), etc.
  - Verification of format, binding technique if applicable, finishing and cutting edges
  - Visual inspection of security features – presence of watermark, iridescent elements, optical variable elements (OVI, DOVIDs), security threads, coloured fibres, latent image, see-through register, etc.
  - Visual inspection of printing processes – intaglio, letterpress, thermal mass transfer, thermographic printing, etc.
  - Visual inspection of numbering format
  - Observation of perforations, if applicable – document number, ghost image of bearer
  - Visual inspection of each entry, if applicable – typeface / font of variable data, stamp impressions, dry stamps, visa or tax stickers, etc.

- Visual inspection of biographical data special attention has to be paid to the date of birth, sex, colour of eyes and hair versus photo / image of bearer
- Visual inspection of issuance details and validity dates.
- Visual inspection of photo / image of bearer if present
- Visual inspection of laminate if present – crimped, loose, with air bubbles, etc.
- Visual inspection of binding thread if present
- Tactile inspection of raised laser engraving and intaglio printing, if applicable

● Comprehensive microscopic examination (stereomicroscope, macroscope, comparison microscope)

- Recognition of the various printing techniques present
- Check type font (e.g. MRZ must be OCR B)
- Examination of the perforations – production techniques, check if manual perforations are present
- Examination of the edges – pay special attention to the corners and check for the presence of irregularities (e.g. hand cutting of page or photograph corners)
- Examination of the binding thread if present – type of thread, color(s), tension and integrity of the thread, number of stitches and stitching holes
- Examination of other fixing elements of a booklet, if applicable (e.g. staples)
- Recognition of printing techniques used for designation of items and variable data, if applicable – pay special attention to issuance and validity dates, date of birth, sex and height of bearer
- Examination of the substrate surface
- Examination of security features – planchettes, fibres, security thread, latent image, miniprint, microprint, nanoprint, optical variable elements, etc.
- Examination of biographical pages with laminates – check corners, check substrates and personalisation data for the presence of damages, cuts, crimped zones, air bubbles, blurring of data, etc.
- Examination of the edges of the laminate around the photo of bearer and along the folding axis – check for cutting edges, double laminates, glue residue
- If the biographical pages are attached either to front or back cover pages, examination of the outer side of the cover – check for indention of X-cut in the area of the photo and abnormal height due to glue residue
- Examination of photo of bearer, if applicable – check photographic layer, corners (clean cuts, not by hand), edges (no glue residues, fibre disturbance, smudging of background printing or loose paper residue should be visible)
- Examination of the photo fixing technique – eyelets, staples (check adjacent page for match of indentations)
- Examination of photo security procedure– embossed stamps, ink stamps, etc.: check form and ink of stamp on the photo and continuity on the adjacent page zone; laminates: check printed and security elements on the photo area for similarity of production techniques and matching of adjacent parts of these elements

- Examination of digital image of bearer, if applicable – recognition of printing technique and screening, check the background for evidence of erasure

● Examination with visible light
● Oblique/side light:

- Examination of printing techniques (e.g. intaglio, thermographic printing)
- Examination of dry stamps, tank tracking and other embossed impressions – check quality of embossing, smoothness of paper surface, match of the embossing between front and back of page, using tweezers or needle, or raise photo and check congruence of embossing between surfaces corresponding to each other
- Examination of watermarks (3D-structure)
- Examination of substrate surface – check for defects (rough surface) which may occur by erasure

● Transmitted light:

- Examination of watermarks and security threads
- Examination of the structure of the substrate – paper formation; also check for lighter / darker areas that may indicate abrasion, the presence of glue residues or the presence of multiple layers
- Examination of the substrate under the photo, tax stamps, stickers, if applicable – check for structure damages, dark / light zones, overwritten entries)
- Examination of perforations – check quality and alignment between pages, if applicable (e.g. numbering, photo, rip cuts)
- If evidence of alteration (mechanical erasure) is detected, analyse according to the respective procedure

● Examination with UV light (dark room, all pages if applicable)

- Examination of UV-fluorescence behaviour of substrate – long and short-wave UV excitation; verify that there is no visible watermark imitation on paper
- Examination of fluorescent security features – planchettes, fibres, printing inks, security thread, sewing thread, etc.; use long and short-wave UV excitation and if needed transmitted UV
- If evidence of alteration is detected, analyse according to the respective procedure

● Examination of luminescence and absorption / reflection behaviour (video-spectral comparator or equivalent set-up)

- Examination of IR absorbance / reflection of inks and substrates (e.g. metameric pairs of inks)

- Examination of luminescence reactions of inks and substrates – check especially the individual data (numbering, name, validity dates, date of birth, height, sex, colour of eyes and hair, if applicable)
- If evidence of alteration is detected, analyse them according to the respective procedure

● Other examinations

- Examination of scrambled indicia – use adequate decoder (lenses or software, e.g. video-spectral comparator)
- Examination of anti-Stokes effect of security inks
- Examination of retro-reflective security features – special laminates: use handheld device or video-spectral comparator
- Examination of magnetic properties of inks, using adequate detector
- Verify check digits, if applicable
- Check MRZ, if applicable
- Check barcodes for consistency with visible data, if applicable
- Check magnetic stripes / chips for consistency with visible data, if applicable
- Check hidden information in DOVIDs, if applicable – e.g. with laser lamp
- Check reactions of substrate / inks to solvents, if applicable

12. RECORDING AND INTERPRETATION OF RESULTS

Record the relevant results of the various examinations above according to the laboratory practice in place and save all relevant images securely.

Consider the significance of these results both individually and in combination. The interpretation of the results may depend on the existence of a specimen document or bona fide description details of the security document, as well as on the experience of the expert.

Conclusions in any report or statement may include, among others, the following forms:

- Confirmation of the authenticity or otherwise of the security document, either as a whole or part of it
- Reporting on evidence found of alteration or addition to a document
- Reporting on the techniques used for counterfeiting / forging the various parts / features of the questioned document
- Reporting if two or more falsifications have similar counterfeiting of forging characteristics, and eventually assignment of falsifications to a class
- Reporting on the manipulation of the photo / image of bearer
- Reporting whether it is a fantasy or camouflage document
- Reporting on the connection between seized materials and/or equipment and the production of counterfeit, fantasy or camouflage documents

The extent of information included in the report or statement should be considered so that another expert with similar experience may identify and validate the same results, but always bearing in mind that, as we are dealing with (high) security documents, this information should not disclose confidential aspects nor contribute to improve the counterfeiter's ability.

13. QUALITY ASSURANCE AND COMPETENCY

A competent examiner should be able to select the adequate techniques for every specific case and to carry out all the procedures and use the necessary equipment to obtain the best results.

A competent examiner should be able to carry out a full comparison between documents or between a document and bona fide description details and assess the significance of similarities and differences between them. He must be aware of the limitations of the method, especially when he has to perform an evaluation of the level of technological development of a questioned document with no specimen or description details available and weigh the conclusions while considering these limitations.

The relevant competencies to perform examinations of security documents are summarised in the document "Skills and Knowledge Base for European Forensic Document Examiners".

Case reports should always be checked by another expert before being released to the client.

14. BIBLIOGRAPHY

- Hilton, Ordway; "Scientific Examination of Questioned Documents", 1993
- Harrison, Wilson R.; "Suspect Documents – Their Scientific Examination", 1981
- Ellen, David; "The Scientific Examination of Documents – Methods and Techniques", 1997
- Renesse, Rudolf L. van; "Optical Document Security", 1998

APPENDIX 3 – OVERVIEW PROCEDURE FOR EXAMINATION OF DAMAGED DOCUMENTS

1. INTRODUCTION

Many of the procedures described in this document have not been properly validated and must therefore be used with extreme care as, depending on the circumstances, they may do more harm than good.

The purpose of the examinations described in this document is the (partial) reconstruction of damaged documents and the retrieval of the information thereon.

The method can also be applied to secure information from documents for which destruction is inevitable.

The type of examination depends on the nature of the damages done to the document. The procedures include non-destructive and (semi-)destructive techniques.

The list of procedures described in this document is not exhaustive.

2. SCOPE

This procedure may be used to determine the contents of documents which have been damaged by water, fire, mechanical tearing or shredding, biological action etc.

The examination does not include inspection of these damages to determine possible alterations to the document.

This procedure is applicable when we need:

- to stop the progressive process of document destruction;
- to handle a damaged document;
- to reconstruct and conserve a document;
- to uncover the information stored in a damaged document.

3. PRINCIPLES

To start this type of examination it is necessary to determine the manner in which the document has been damaged:

- Thermal action: burning or heating;
- Chemical action: exposure to solvents, water etc.
- Mechanical action: tearing, cutting, shredding or abrasion;
- Biological action: bacteria, fungi, insects or rodents.

The techniques used to examine damaged documents are mentioned below. The examiner decides which tests are to be undertaken and their order:

- Microscopic examination
- Transmitted light
- Specular reflection
- Oblique light
- Comparison with other (undamaged) copies
- Examination of handwriting, typewriting etc.
- IR-Luminescence
- IR-Absorbance
- Short-wave UV-fluorescence
- Long-wave UV-fluorescence
- UV-reflectance
- Filters: monochrome and dichroic
- Electrostatic detection equipment
- Digital image enhancement
- Chemical analysis of solvent residues in the paper
- Freeze drying (lyophilisation)

It may also be appropriate in some instances to employ ink analysis techniques such as Thin Layer Chromatography and Microspectrophotometry. These techniques are not described here.

4. CROSS REFERENCES

- Application of Luminescence to the Examination of Documents
- NIR Absorption and Reflection Examination of Documents
- Examination of Indented Impressions
- Stamps and Stamp Impressions
- Examination of Intersecting lines
- Examination of Alterations
- Non-destructive Paper Examination

5. PRESERVATION AND HANDLING OF ITEMS

The preservation of damaged documents follows specific procedures depending on the manner the document was affected.

Burned documents

The features of burned documents:

- Documents with soot or smoke (dirty)

- Documents damaged by heat. The examination shows abnormal stiffness
- Documents damaged by the flames

If possible do not attempt to remove documents from the original container and transport the container to the laboratory.

If the original container cannot be transported to the laboratory, it is necessary to transfer the documents to another receptacle. The contents are taken as a mass and not as small packets by sliding a metal sheet under the pile.

For transportation the burned documents may be placed in a cardboard box marked “this way up”, lined with cotton wool. Preservation and conservation of a burned document is done by fixing (see section 11.1).

Wet documents

The features of wet documents:

- Moist documents: traces of wetness but no flow
- Wet documents: the document is streaming

If a document is wet and we need to immediately stop its process of deterioration, the document should be placed in a sealed plastic bag and placed in a freezer to be quickly frozen. Freezing allows to defer treatment and to think about future actions. It makes it possible to stabilize the document as quickly as possible, to stop the processes of degradation: deformation, dissolution of inks and glues and to stop the microbiological development. Phase two consists of freeze drying the document under vacuum. Single layered documents may be dried by placing them on absorbent filter paper and exposing them to reduced humidity at normal temperature in a ventilated area.

If documents are exposed to moist, the air drying is recommended.

Torn, cut or shredded documents

Shredded items should be submitted with as little disturbance as possible, in the shredder’s container or waste-paper bin in which they were found if possible. Single, torn or cut documents must be packaged in a cardboard box or in a plastic envelope in such a way that the document can sustain no further damage.

Stopping further deterioration

Checking the pH of wet documents with indicator paper is useful to see if an urgent measure must be taken at a crime scene to stop certain deterioration processes. Control of the pH must be done directly on arrival at the lab using a standard method to determine the pH value of paper fibres in a water extract. If the documents need to be preserved for several years, acidic documents must be preserved in a permanent paper envelope with an alkaline reserve. If the document is acidic it should be neutralized using a solution of calcium or sodium carbonate.

After drying the action of bacteria and fungi can be stopped by treatment with gamma radiation.

The handling of items must be done with the respect to the preservation conditions.

Usual and specific anti-contamination precautions must be taken when examining items which have not been treated with the proposed preservation methods.

6. EQUIPMENT/INSTRUMENTATION/OPERATING CONDITIONS

The basic equipment needed for the examination of damaged documents is listed below:

- A stereo microscope
- Equipment for the examination of luminescent and reflective properties in the UV, visible and NIR region.
- Sources for oblique and transmitted light
- Electrostatic detection equipment
- In cases where digital image enhancement is used, a scanner or digital camera with sufficient resolution, a computer and a programme with image enhancement facilities are needed
- Irradiation equipment with gamma and UV sources.
- Equipment for pH measurement.
- Equipment for freeze drying
- Freezer
- Humidity Cabinet for re-hydration of documents

7. REAGENTS AND MATERIALS

- pH paper
- Liquid nitrogen

8. HEALTH AND SAFETY

Examiners must take proper protective measures when working with chemicals, liquid nitrogen, strong light sources, high voltage and gamma radiation.

Appropriate biological safeguard measures against allergy and mycosis must be taken.

It is the responsibility of the user of this method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

9. PREPARATION AND CALIBRATION OF EQUIPMENT AND REAGENTS

It is the responsibility of the operator to calibrate the equipment according to the manufacturers specifications.

10. PROCEDURE

The most frequently applied methods for the forensic examination of damaged documents are described below. The Document Examiner must decide on the most appropriate technique for the case. This decision must be based on the extent of damage to the document and the way in which the original writing/printing on the document was produced.

Primary inspection of the deteriorated documents allows us to establish the method in which they were affected and also if this process is ongoing or has (been) stopped. In order to be safe, it is recommended that the documents should be photographed directly in the shape they are received and also at the different step of examination because there is a risk to lose information

10.1. Burned documents

10.1.1. Separation and stabilization

The examiner must be aware that the following techniques may influence the result of further optical examination. Documents burned in a closed container react differently from those burned in the open air. Depending on the number of sheets, their proximity to one another and the extent of charring, they adhere strongly or can be separated easily. If they adhere strongly, they may remain fairly flat while their edges might curl and twist. Often the examination of burned documents starts with the separation of numerous layers. This may be done by[124]:

- placing them in a solution of boric acid 1,2% and sodium hydroxide 0,4% for about 30 minutes. After separation they can be placed in a solution of 10% formalin for 5 minutes to smooth them out.
- placing them into a solution of 3% sodium bicarbonate for 30 minutes at 50°C.
- treatment with a 3% solution of polyvinyl acetate in acetone, applied with a pipette. Due to the sticky nature of polyvinyl acetate the document should be placed on a glass surface sprayed with a diluted silicon oil solution.
- applying a solution of glycerine/isopropanol/water – 3/5/20 with a pipette.

The success depends on the density of the ink as well as the degree of charring. It is for the optical methods of examination that the glycerin / isopropanol / water solution is applied

124 G.E. Calderon, "The Examination and Preservation of Burned Documents", International Criminal Police Review, no 176 (1964), pp 70-81

because it makes it possible to accentuate the reflectivity values between the different parts a charred document. Water communicates variable reflective values, the alcohol acts as a wetting agent and glycerine is a hygroscopic substance that partly retains the water content. Using the GIW solution, the readings of the fragments are made during each step of the treatment:

- before immersion
- when the fragment is lying on the surface of the solution
- Under solution
- While it drips
- After drying

What is not decipherable at one time may be at another.

Photographies are made during each step of the treatment.

10.1.2. Optical methods of examination

After the above preparation examine the document using (a combination of) the following techniques: visual/microscopic examination, oblique light, UV/VIS/NIR luminescence, NIR reflectance, digital image enhancement, polarized light, etc.

For an explanation of the use of various techniques in the examination of burned documents see the EDEWG procedures:

- Application of Luminescence to the Examination of Documents
- NIR Absorption and Reflection Examination of Documents
- Examination of Alterations

10.1.3. Photographic methods of examination

By storing a burned document between two photographic plates[125] original writing may be revealed. For this method a photographic darkroom is needed. The document is exposed to UV radiation for a couple of minutes after which it is placed between two undeveloped photographic plates and stored in a light proof box under a heavy weight to ensure the best possible contact. After a contact period of two weeks the plates are developed in a standard way. For the recovery of the original writing on the burned document various methods may be applied:

10.1.4. Chemical methods of examination

<u>Treatment with peroxide.</u>

[125] J. Tyrrell, "The Decipherment of Charred Documents", Journal of Criminal Law and Criminology (1931-1951), Vol. 30, No. 2 (Jul. - Aug., 1939), pp. 236-242

This treatment is aimed at bleaching the blackened paper to enhance contrast with the writing. To achieve this, the burned paper must be kept for 48 hours in a 10-12% peroxide solution. After drying, the writing and other printed features on the document appear with a dark colour on a white background.

Treatment with chloral hydrate[126]

The burned document is submerged in an alcoholic 2.5% chloral hydrate solution or a 25% solution is applied with a camel haired brush. The soaked paper is then taken out and dried at a 60°C. The operation is be repeated in a couple of times till numerous crystals have formed at the surface. Then the document is finally submerged in the same solution to which 10% glycerine has been added. After drying again at 60°C, the paper surface remains white with the exception of the written or printed features which absorb the chloral hydrate to a lesser extent.

Treatment with silver nitrate[127] (lunar caustic) solution

The document is soaked in a 5% aqueous silver nitrate solution. The document is kept intact between two sheets of glass. If the document is quite distorted, two small objects may be placed under opposite ends of the top glass plate to keep it from coming into contact with the fragment. A document thus treated should be protected from direct sunlight. Within three hours any writing which is developed appears black against the grey background of the paper. The writing can be fixed by rinsing the document in water several times and drying rapidly between rinsings. This method appears to be more effective with most pen or typewriting inks. Washable aniline dye inks do not react well and heavily loaded papers respond much better than normal paper.

10.1.5. Thermal methods of examination[128]

This type of treatment is a last resort, but very good results have been obtained in the past. Generally speaking the writing materials are more resistant to high temperatures than the paper. Therefore a contrast may be obtained at elevated temperatures (calcinations) between the background, which will become almost white, and the graphical features. In order to perform this procedure the paper must be immersed in a 10% solution of sodium silicate, then lifted from the solution and placed on a wire mesh screen. After the document is drained, it is immersed in a 10% solution of calcium chloride, then again lifted and drained on the wire screen. The document is then washed and re-immersed in the solution of sodium silicate.

[126] D. A. Black, "Decipherment of Charred Documents", Journal of Criminal Law and Criminology (1931-1951), Vol. 38, No. 5 (Jan. - Feb., 1948), pp. 542-546
D. Doud, "Charred Documents, Their Handling and Decipherment. A Summary of Available Methods for Treating Burnt Papers", The Journal of Criminal Law, Criminology, and Police Science, Vol. 43, No. 6 (Mar. - Apr., 1953), pp. 812-826
[127] J. Grant, "Decipherment of Charred Documents, Some Recent Work and a New Method,"Analyst, Vol 67 (1941) pp. 42-47
[128] J.T. Walker and P.A. Glass, "Visualization of Writings on Charred Paper", Journal of Criminal Law, Criminology and Police Science, Vol. 42 (1951-52), pp. 112-113.

Following this immersion, the document is dried in a warm oven. Finally, it is carefully placed between two plates of heat-resistant glass which are then heated for two hours at 500 degrees centigrade. If successful, the document will change to white ash. If the writing was an iron base ink, it should show up as a red deposit, and if it were pencil, the writing should appear as a black deposit. The limitations to this procedure are obvious. Noteworthy of mention is that washable ink and ball pen ink leave no recognizable deposits.

After the burned paper has been extended and writing or drawings have been disclosed, a more permanent immobilisation of the document can be obtained by spraying with a solution based on polymeric material or lacquer or by one of restorations techniques described in some detail in section 11.3 digital and manual reconstruction.

10.2. Wet documents

Immersed in water or other solvents, paper suffers modifications, the extent of which depends on parameters such as solvent type, solvent temperature, type of paper fibres and sizing, paper thickness, porosity, finishing, the duration and finally the nature of the drying and preservation condition.

Solvents will cause specific writing or printing containing soluble dyes to dissolve and /or diffuse into the support causing a partial or total bleaching of the information.

There are situations when wet documents during drying have become glued together. A controlled moistening (wetting) is then necessary in ordered to separate these. This can be done by placing the documents on a humid bowl of sand, above a water reservoir in an enclosed container such as within a humidity cabinet or in a jet stream of water vapour. Depending on the nature of the stack of documents separation can hence take place by either carefully pulling them apart in a moistened state or by freeze-drying (lyophilisation). The first method of separation is quite hazardous and its success will greatly depend on the strength of the paper and the skill of the examiner. Freeze-drying on the other hand is a very safe method for separating wet documents as the documents are not separated by manual force but by preventing the sizing agents from gluing pages together. With the ice crystals holding the pages apart during this process, the final result is a document of which the pages have become unglued and readily accessible again.

Drying of single (non-glued) wet documents may be done by one of the following absorption or vaporization methods:

<u>drying by absorption</u>

This may be done by placing the document between 2 pieces of blotting paper. This method is recommended for small documents. Change the blotters regularly especially at the beginning of drying freeze-drying

This is the most preferred method because freezing the document stops or significantly slows down processes such as dissolving of the inks and chemical and biological degradation which may do further damage to the document. A disadvantage of this method is that it is a slow process and therefore more time consuming than the other drying methods. The procedure consists of a rapid freezing of the document and then setting it in a vacuum chamber. Freezing must be done at low temperature (-30, -40 °) which allows to favor the formation of finer ice crystals which is less damageable for the documents. The vacuum causes the ice to sublimate.

hot air drying

This has the advantage of a rapid execution but the disadvantage of losing the paper's elasticity and the danger of accelerating the growth of micro-organisms at elevated temperatures. This procedure consists of exposing the document to an air stream at room temperature or above. The deterrence of further deterioration can be done by controlling the pH of documents in the lab, before and after drying, using a paper indicator. The document should be neutralized using a calcium or magnesium carbonate solution.

Fan drying

Another less harmful alternative is that of fans. Fans blowing on the documents circulate the air and facilitate evaporation. Ventilation drying can be accelerated with hand dryers with a cold air blast. In the case of bundles, when the top document is dry enough to be handled safely, lift it up and place it on another surface where it will continue to dry. Once removed, the next one is better exposed to allow evaporation. Drying also accelerates as soon as the stack can be safely divided into smaller stacks.

To further reconstruct the original entries on the document optical techniques such as UV/VIS/IR reflectance and luminescence may be applied. For further instructions on their use the appropriate EDEWG procedure may be consulted.

10.3. Torn, cut or shredded documents.

The task of reconstructing torn and shredded documents varies from straightforward to unachievable depending on factors such as the total quantity involved, the degree of fragmentation and the distinctiveness of any target items. Because of this unpredictability, a dialogue with the submitting officer is vital to ensure the examination is conducted in the most efficient way. Where many shredded documents are involved the examination must be staged, and the officer consulted at the end of each stage. The dialogue may also include viewing of partial results by the investigating officer.

Shredded items should be submitted with as little disturbance as possible, in the shredder's container or waste-paper bin in which they were found if possible.

The separation procedure is conducted in stages from a course to a fine separation. The procedure starts with an initial separation of the paper fragments by: paper colour, alignment, direction of shredding, the writing instrument used, the writing material used, etc.

If the number of fragments in each category is large then subsequent sorting may be necessary. This is done using factors such as the UV luminescence of the paper, typeface, colour and type of ink/toner, margins, presence of laid lines, etc. as appropriate.

Depending on the amount of documents to be reconstructed and the necessity of performing other types of examinations such as DNA or fingerprints on the fragments they may be reconstructed digitally or manually.

Digital reconstruction can take place by scanning each fragment separately and reconstructing the fragments in layers in e.g. Adobe Photoshop. Other methods exist in the meantime to reassemble fragmented documents digitally. For example the developed with the Fraunhofer Institut the ePuzzle https://youtu.be/8PK_QRdT0kY.

For the manual reconstruction of the torn or cut documents different methods may be used, such as:

- special transparent paper for invisible mending, which is self-adhesive and extremely thin. This special paper must comply with the newest principles for the preservation of cellulose fibres and be removable with water from stable paper surfaces, if stored under normal climate conditions. This special paper is also buffered with $CaCO_3$.
- interventions can be done either dry or wet using Japanese paper with starch glue or Klucel G ® (ethanol based); this choice will depend on the nature of the paper and the nature of the ink. Always perform a solubility test of the cotton staple inks and drop of water before any intervention. Concerning a yellowed paper, burned, one will prefer drying techniques or techniques with alcoholic glues
- sticky-faced boards or low-tack plastic film. The choice of these media will depend on a number of factors; film tends to be more adhesive than boards, smaller/thinner fragments and strips may not adhere reliably to boards whereas larger/wider fragments and strips may not readily peel off film for re-positioning.
- For double-sided documents transparent adhesive film will be used. NESCHEN Filmolux is designed to be re-positionable within 24 hours but not after. This may be important on occasions where reconstructions are partial or provisional and may need amendment after viewing by the investigating officer. The reconstructed document should be covered with transparent non-sticky plastic such as OHP film so that it can be picked up to view both sides.

- Another method for the reconstruction of damaged documents is the ARMOURING method. Here the document must be fitted on a plastic bolt, with the purled margins covered, the enfolded lines or the other damaged areas with pieces or strips of Japanese paper (6g/m2) and then infiltrated with carboxyl-methyl-cellulose sodium salt (CMC-Na).
- In order to preserve the document, we must place it between two 4 microns low density polyethylene foils. After that these three layers are placed between two other foils of Japanese paper and finally, all these layers are placed between two pieces of silicone paper. This sandwich is introduced between two surfaces which are heated until the melting temperature of polyethylene and lightly pressed. The result is a resistant, flexible document easy to handle and store.
- Another possible technique for fragile documents having multiple tears or consist of many fragments is the use of the suction table: the document or pieces are moistened several times with the vaporizer, re-glued with a cellulose glue (tylose MH 300 P to 0 , 5g / liter) if they are degraded by mold and lined with a sheet of Japanese paper 6g / m2. Clogging on a suction table with pulp made of cellulose may also be useful. The principle is to insert paper grafts where there are gaps and tears. For a better adhesion of Japanese paper or grafts, a press release is often necessary. For torn documents, use 6g / m2 Japan paper strips and starch glue or hydroxypropyl cellulose glue (Klucel G®).

10.4. Biologically damaged documents

Bacteria and/or fungi will degrade a document by attacking the writing substances, the cellulose fibres or the paper’s sizing agent. Before any intervention, check the state of activity and the power of degradation of the molds: it is not because there are traces of visible damage that they are still active or under development

If it is relevant for further investigation, contact an expert to establish the nature of degradation, bacteria, fungi, algae, lichens, insects, etc.

Bio-degradation blocking is realized through physical and chemical treatments.

There are many chemical and physical antifungal treatments. We will retain here only the most frequently used techniques:

<u>Physical treatment:</u>

- Documents must be carefully dusted beforehand because dust can ignite. High frequency currents cause a uniform rapid temperature rise (the temperature is maintained between 90 and 100 ° C) of the treated material killing insects and

fungi. The effect propagates from the centre to the periphery. Currents of 18-30 MHz with a power of 8 KW must be applied for 10 minutes.
- UV-irradiation disinfects the paper surface of some documents but the treatment is associated with an acceleration ageing of the document.
- Gamma irradiation is used for the complete elimination of fungi infection. For this treatment a dosage of 10 KGy or 1 MRad has proven to be effective.
- After this treatment, the bacterial and actinomycete infections remain active.
- Repeated frost and thawing of the document. Freezing the document over and over 4-5 times can destroy some biological agents completely.

Dehydration

Dehydration consists of lowering or stopping the availability of water necessary for the growth of microorganisms. Dehydration can be achieved by freeze-driyng. Freeze-drying is more effective than freezing due to the removal of water. Indeed, in the process of manual defrosting, the humidity included in the paper is very important which can activate dry conidia.

Chemical treatment:

Chemical treatment may be done with non-halogenous substances such as: formic aldehyde, ethylene oxide, methyl format, hydrocyanic acid, ortho-phenyl sodium carbonate, isopropyl cresol, mercuric phenyl acetate, etc. or halogenous substances such as: paradichloro-benzene, phenol’s chloride derivatives.

Ethanol is still used today as a disinfectant, it appears to be the least toxic and the most effective antifungal products. The higher effect is reported for ethanol concentrations between 50% and 80% in aqueous solution (the water carries the alcohol into the cytoplasm). Ethanol / water solutions are usually applied by spraying or immersion. However this solution does not have a sporicidal effect and a regrowth of the fungi may occur. Ethanol can cause changes on paper: loss of gloss, increase in opacity. Ethanol can also dissolve inks and adhesives, and so solubility tests have to be performed previously to treatment.

Calcium propionate is used both in aqueous and in ethanolic solution. The solution of propionate of calcium / ethanol is still more effective because the ability of ethanol to act as a vehicle for the calcium propionate molecule through the fungal cell membrane.

Parabens are used in a mixture of methylparaben (0,5%) and propylparaben (1%) in an 85% ethanolic solution combined with calcium proponate (5%).

When washing the document we must use distilled water and a quaternary ammonium salt. The document is brushed entirely or only the surfaces affected by biological degradation.

- inter-foiling; with this method sheets of blotting paper or any other absorbent paper impregnated with an active volatile product are placed between the infected pages. These stacks are then kept in synthetic, waterproof envelopes, at temperatures of 25-300°C. The exposure time differs from one substance to another.
- the gas process; this must be done in a specially sealed stove, thermo-control from 20-700°C with the ability to work in both vacuum and overpressure. The document is introduced into the stove which is then hermetically closed and filled with active gas. After the treatment period two successive vacuum operations must be performed to so called "air wash" the documents. For EO, 4 to 6 washes of 8 hours must be performed to meet the permissible exposure limit. After this the documents are removed for further restoration and/or examination.

According to the studies, for chemical antifungals, calcium propionate, parabens and ethanol are the ones that combine minor health effects with the least negative impact on paper. Among the three, parabens have the best antifungal properties. Regarding physical methods, dehydration seems to have the best combination of antifungal effect and minor changes in the properties of paper, it is the simplest and most harmless way to stop microbial growth.

Some restoration technologies use biological entities in the form of enzymes or bacteria. The treatment with enzymes may be used successfully on clearing the pages of some flooded books. The residual layer of starch glue from the paper may be removed with specific enzymes incorporated into a gel. These are commercially available and applied by direct cushioning.

11. BIBLIOGRAPHY

- G.E. Calderon, "The Examination and Preservation of Burned Documents", International Criminal Police Review, no 176 (1964), pp 70-81
- J. Tyrrell, "The Decipherment of Charred Documents", Journal of Criminal Law and Criminology (1931-1951), Vol. 30, No. 2 (Jul. - Aug., 1939), pp. 236-242
- D. A. Black, "Decipherment of Charred Documents", Journal of Criminal Law and Criminology (1931-1951), Vol. 38, No. 5 (Jan. - Feb., 1948), pp. 542-546
- D. Doud, "Charred Documents, Their Handling and Decipherment. A Summary of Available Methods for Treating Burnt Papers", The Journal of Criminal Law, Criminology, and Police Science, Vol. 43, No. 6 (Mar. - Apr., 1953), pp. 812-826
- J. Grant, "Decipherment of Charred Documents, Some Recent Work and a New Method,"Analyst, Vol 67 (1941) pp. 42-47
- J.T. Walker and P.A. Glass, "Visualization of Writings on Charred Paper", Journal of Criminal Law, Criminology and Police Science, Vol. 42 (1951-52), pp. 112-113.
- S.Sequeira, E.J. Cabrita, M.F.Macedo , " Antifungals on paper conservation : An overview", International Biodeterioration and Biodegradation 74, 2012, pp.67-86.

- S.A Dobrusina, “Increasing the durability of paper when restauring documents by paper pulp filling process”, ICOM Committee for Conservation, 9th triennal meeting, Dresden, Preprints, vol.2, pp.456-458, 1990.
- J.McAUSLAND and P.STEVENS, “Techniques of lining for the support of fragile works of art on paper”, The Paper Conservator, Journal of the Institute of paper Conservation, volume 4, 1979 pp. 33 à 44.
- T-P. Nguyen and S.Bouvet, Etude comparative des procédés de renforcement des papiers par thermocollage, Actualités de la Conservation, n°24, juillet-décembre 2005.

APPENDIX 4 – OVERVIEW PROCEDURE FOR EXAMINATION OF ALTERATIONS

1. INTRODUCTION

The examination of alterations is one of the most frequently encountered activities of a forensic document examiner. Examples of alteration encountered include: altered amounts of bank cheques, altered personal details in identity documents, obliterated entries in financial accounts, additions or alterations of wills. In principle, all documents that represent a certain value are vulnerable to the alteration of written or printed entries.

The purpose of examinations described in this procedure is to identify whether alterations have been made to the content of a document and to determine any previous entries. (For the purpose of this procedure `alterations` are taken to include additions, obliteration and erasures)

2. SCOPE

This document is applicable to:

- Alterations made deliberately or occurring naturally or by mistake, to printed, typewritten or handwritten information on a document. Alterations to other materials and the identification of inks are outside the scope of this document. Alterations made by counterfeiting the entire document and introducing changes in this way, including photocopy composites, are also excluded. Alterations may take the form of additions to a document, changes to, erasures of or obliteration of existing entries.
- Examination of these alterations or use of ink comparisons to determine the sequence in which a document was completed, or whether pages of a multiple-page document have been substituted, removed or added fall outside the scope of this document. There are sequencing examinations and will be dealt with elsewhere but may involve some of the techniques described here.

3. PRINCIPLES

The principle of examination of alterations is to look for inconsistencies in a document. This can be done by comparing the questioned area(s)/page(s) with other parts of the document or with reference copies. Once inconsistencies are found the appropriate technique(s) listed in this method must be applied to thoroughly examine the document for alterations.

The techniques used to examine documents for alterations are shown below. The examiner decides which tests are to be undertaken and in which order the tests are performed.

<u>Visual examination and comparison</u>

- Visual (microscopic) examination
- Transmitted Light
- Reflected light on both sides of the paper
- Oblique light on both sides of the paper
- Examination and comparison with other (unaltered) copies
- Examination of handwriting, typewriting etc.

Specialised techniques

- IR-luminescence
- IR- absorbance
- Short wave Ultra-Violet
- Long wave Ultra-Violet
- Filters – single colour and dichroic
- Electrostatic detection equipment
- Digital image enhancement

It may also be appropriate in some instances to employ ink analysis techniques such as Thin Layer Chromatography and Microspectrophotometery. These techniques are not described here.

4. GLOSSARY

Alteration - A modification made to a document by physical, mechanical or chemical means, either deliberately, by mistake or by natural occurrence.

Obliteration - Rendering information on a document invisible or illegible by covering-up with extraneous substance such as correction tape/fluid or by obscuring with inks.

Addition - Entries added to a document, usually at a later time to the making of the original entries.

Erasure - The removal of original entries on a document through physical or chemical means. The erased entries may be overwritten with new information.

5. CROSS REFERENCES

- Application of Luminescence to the Examination of Documents
- NIR Absorption and Reflection Examination of Documents
- Stamps and Stamp Impressions
- Examination of Intersecting lines
- Non- destructive Paper Examination
- Toner Examination

- The Examination of Inkjet Printed Documents
- Recognition of Printing Techniques
- Examination of Security Documents
- Ink Analysis by TLC

6. PRESERVATION AND HANDLING OF ITEMS

Precaution to prevent contamination and to preserve other traces, like fingerprints or DNA, must be taken.

If electrostatic detection examination or latent prints examination is to be done, precautionary measures must be taken to prevent introducing fingerprints or other types of impressions onto the document.

7. EQUIPMENT / INSTRUMENTATION / OPERATING CONDITIONS

The basic equipment needed for the examination of alterations is listed below.

- Microscopes
- Sources for oblique and transmitted lights
- Equipment for the examination of luminescent and reflective properties in the UV, visible and NIR regions
- Electrostatic detection equipment
- In cases where digital image enhancement is used, a scanner with sufficient resolution, a computer and a programme with image enhancement facilities are needed.

8. HEALTH AND SAFETY

Examiners must take proper protective measures when working with strong light sources (luminescence) and high voltage (electrostatic equipment).

This method does not address all the safety concerns associated with its use. It is the responsibility of the user of this method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

9. PROCEDURE

The most frequently applied methods for the forensic examination of alterations in documents are described below in some details. However, each case may require a different approach and these protocols are supplied for guidance only. The document examiner must decide on the most appropriate technique for the case.

It is beneficial to know the appearance of a genuine, unaltered document prior to the commencement of the examination. Where possible a control genuine document should be obtained for reference. A comparison between the questioned item and a "control", or between the pages of the questioned item itself should be made using the different lighting and luminescence techniques available. Differences between the items compared may indicate attempted alteration.

9.1. Visual (microscopic) examination

Evidence pointing to the presence of an alteration and a determination of its nature and the original text, can often be detected by visual examination of the document and its contents. Differences between two inks may be apparent. Examination is normally carried out both with the unaided eye as well as with the aid of a stereomicroscope using oblique or transmitted lighting. A magnified photocopy of the alteration can sometimes be of assistance in note taking. Visual and stereomicroscopic examination may be used to distinguish between different types of inks or writing instruments. Differences in ink type, colour, density, width of the ink line, line quality, etc. may indicate the presence of an alteration.

Close examination of an obliterated entry will often reveal sufficient parts of the obliterated text for it to be interpreted. If a sufficient part of the obliterated entry is uncovered, interpretation may be assisted by making an enlarged photograph or photocopy and then removing (for example with correction fluid) those lines that are clearly part of the obliterating ink. The fragments of the original entry remaining, once the confusing obliterating lines have been removed, may be sufficient for the interpretation of the original entry. Something similar may be accomplished by scanning the document after which the obliterating ink may be removed from the image using image enhancement software.

9.2. Transmitted light

If the document under examination is (partially) translucent or transparent, intensified light spots under examination with transmitted light may indicate attempted alteration. Watermarks may also be evident. Depending on the circumstances the transmitted light, shone through the document, may be from a diffuse low intensity light source (e.g. a light box) or from a focussed high intensity source (e.g. fibre optic light source). Care should be taken not to scorch the document.

Transmitted light examination is useful to identify areas of varying thickness, possibly caused by mechanical erasure or to examine and interpret text obliterated by opaque substances (for example address labels, correction fluid, etc).

9.3. Reflected light

Examining a document at various angles using illumination from an extended light source can show variations in surface reflectance as "sheen". The angle of light in relation to the document and the point of view is varied until an acceptable result is obtained. This is often the case when the angle between the eye and the surface of the document is approximately the same as the angle between the document and the light source. Under these circumstances different inks may exhibit different degrees of reflectance, hence if the obliterated ink reflects light differently to the obliterating ink, it may be possible to interpret the original entry. Also, areas of an item where the surface has been disrupted, damaged or changed may reflect light differently to other, undamaged areas. Examine also surface on the reverse side.

9.4. Examination and comparison with other (unaltered) copies

If copies, for example photocopies or carbon copies of the document under examination are available, differences between them will indicate alterations to one of the documents. The copy must be shown to have come from the same source as the questioned document. Comparison may be made by eye, transmitted light, a comparison projector (optical or electronic) or a transparency made from one of the documents to be compared.

It may also be useful to compare the questioned document with other undisputed examples of the questioned document to determine if the observations made are typical or atypical. For instance, it may be common practice for the date on a receipt to be added using a different ink.

9.5. Examination of Handwriting, typewriting etc

Inconsistencies in handwriting, typestyle or layout may indicate alteration, in particular the addition of text. Significant differences in, for example, handwriting or typeface may indicate alteration. A significant change in layout, size or spacing may indicate an entry has been added to a pre-existing space in a document. Similarly, if a typewritten or printed document is supposed to have been produced all at one time, misalignments between characters or paragraphs may indicate that the document has been removed from the typewriter or printer and replaced (in the same or a different machine) before these misaligned entries were made.

9.6. Electrostatic detection equipment

Electrostatic detection equipment may be used to visualise writing impressions or paper surface damage due to e.g. mechanical erasure.

9.7. Specialised lighting techniques

Specialised lighting techniques used to study the luminescence of paper and inks are an important tool in locating alterations but also for the examination of the original entries. These lighting techniques in combination with single colour and dichroic filters allow for the discrimination of inks, the location of staining due to organic solvents, the deciphering of obliterated and erased entries, etc.

A dichroic filter consists of two coloured filters bound together. Each filter passes only part of the spectrum; the combination of the two means that only limited “windows” of wavelength are passed. Very often, a dichroic filter consisting of a red and a green filter is found to gives the best results.

Ultra-violet light may be used to generate luminescence in the visible region of the spectrum. The resulting luminescence is viewed using UV filters to eliminate reflected UV.

Polarised light may be used, with the appropriate viewing filters, to detect striation marks in plastic coating and laminates.

9.8. Image enhancement

The traces of alterations and previous entries can be effectively visualised using image enhancement techniques. The document is scanned, after which the questioned entries are analysed by an image enhancement program. Various operations may be applied for the examination of alterations: contrast, colour separation, colour balance, work in false colour, inverse, embossing, calculation (subtracting or adding different colour channels), etc. It is up to the examiner to choose the most efficient operation or sequence of operations leading to conclusive results.

9.9. Chemical analysis of solvent residues in the paper

Traces of solvent residues in paper after chemical erasure was performed may sometimes be detected by Headspace-GC/MS analysis of the paper. Here volatile substances may be analysed and identified. If no traces of solvents are found this does not mean that no solvent were applied as the solvents applied may be so volatile that they have (almost) completely disappeared from the paper. If this technique is thought appropriate for the case then it should be carried out as soon as possible as the amount of solvent present may be reduced on storage.

9.10. Examination protocols

For the examination of the various types of alteration different analysis protocols may be used, applying the various techniques in a different order. The various types of alteration will be dealt with separately in the following paragraphs.

9.10.1. Obliteration

Obliteration on an entry is often easily noticed. The examination of an obliteration by ink and/or correction fluid is usually done in the following order:

- NIR reflectance examination to see if the obliterating ink and/or correction fluid becomes transparent. Both longpass and a variable continuous bandpass filters are recommended. If the latter is not available dichroic filters may also be applied.
- UV, VIS and IR luminescence to see if the luminescence properties of the original entry are such that it becomes visible through the obliteration. It may sometimes be necessary to examine the luminescence from the rear side of the document, possibly in combination with a translucency agent.

- Visually examine the obliteration by naked eye or under a stereomicroscope with various light techniques as described above. Transmitted light maybe tried with and without a translucency agent, depending on the case.
- In some cases, electrostatic detection of writing indentations on the reverse side of the obliteration or on the page under the obliteration may be tried. The results depend greatly on the amount of force used for the obliteration.
- Digital image enhancement may be tried after scanning the image in reflective or transparent mode.
- Finally, it may be necessary to try to selectively dissolve the obliterating ink or correction fluid using weak solvents, whilst trying to leave the original entry relatively untouched. This method is often quite destructive and must only be tried as a last resort and if allowed by the courts.

9.10.2 Erasure

Erasures are often combined with new entries overlying the erased original entries. Mechanical erasures may often be detected on the basis of substantial paper surface damage or damage to the printing background. Chemical erasures may give the paper a rough feel to it, as if the paper were dried out. Furthermore, fading of background printing (especially UV and fugitive inks) or staining of the paper may be apparent after a chemical erasure.

The examination of an erasure is usually done in the following order:

- Determine if the erasure is mechanical or chemical. A mechanical erasure may become apparent when examined under transmitted and/or oblique light under magnification or with electrostatic detection equipment. A chemical erasure is often more difficult to detect and become apparent under examination by feeling the paper texture, by examination using UV/VIS/NIR luminescence or by visual/microscopic examination of the background printing for possible fading of inks or bleeding of dyes. Dyes incorporated into the paper as a chemical erasure detection system may also bleed and stain the paper in different colours such as purple-black or orange.
- After determining the type of erasure, it is often necessary to try to retrieve as much of the original entries as possible. The table below lists the techniques that may be applied for this purpose and one logical order in which this may be done.

Mechanical Erasure	Chemical Erasure
Transmitted light	NIR reflectance
NIR reflectance	UV/VIS/NIR luminescence
UV/VIS/NIR luminescence	Electrostatic detection
Electrostatic detection	Oblique light

Oblique light	Stereo microscopy
Stereo microscopy	Digital image enhancement
Digital image enhancement	
Transmitted light (translucency agents)	

9.10.3. Addition

Additions to text in documents in the absence of erasure may become apparent due to differences in handwriting, pen pressure, slope, line quality, ink, writing instrument, alignment, line and character spacing, character size, etc. the examination of an addition is usually done in the following order:

- NIR reflectance examination to see if different inks have been used.
- UV, VIS and NIR luminescence for the same reason as above.
- Visually examine the addition by naked eye or under a stereomicroscope with various lighting techniques as described above to check e.g. the characteristics of the ink line or printed characters (toner spatter and texture, ink satellites, etc). Check for misalignment in printed or typewritten documents using a grid or calibrated measuring equipment.
- In some cases, electrostatic detection may be of assistance to determine the order in which the entries on the document were made in relation to the indented writing on the document.
- In photocopies check for multiple trash marks or marks coming from different photocopiers that may indicate that it is not a first-generation copy. Also check for misalignment or evidence of cut-and-paste.
- In the case of crossing ink-lines a determination of the sequence may show an illogical order of preparation.

10. RECORDING AND INTERPRETATION OF RESULTS

The interpretation of results must be based on the findings and the experience of examiner. In the case of examination alterations, the results may have the following forms:

- The confirmation that an alteration has occurred, or the degree of support for such an opinion.
- A degree of support that the document has not been altered.
- The determination of previous entries (it can be done partly or include likely alternative interpretations).
- The determination of the means used to alter the document.

Quite often positive signs of alteration can be detected but it is much more difficult to say when a document has not been altered. In these cases, it is common to indicate that, while no positive evidence of alteration exists, it is possible that an undetectable alteration has occurred.

Results that are prone to subjective interpretation must be examined independently by a second examiner.

The exact requirements for recording casework information will depend on the legal system of the country of jurisdiction. As a minimum, the records should be sufficient in details to allow another examiner, competent in the same area, to be able to identify what has been performed and to assess the findings independently.

It would be very unusual to offer an opinion as to when any change to the document occurred or who made it, although some relative sequencing of the events may be possible

11. QUALITY ASSURANCE AND COMPETENCY

The results of examination must undergo quality control in the laboratory according to the defined procedure. It is recommended for a laboratory to take part in quality assurance programmes (proficiency testing, collaborative studies) organised on international level, e.g. EDEWG.

The competencies relevant to the examination of alterations are summarised in the document: "Skills and Knowledge Base for European Forensic Document Examiners".

12. BIBLIOGRAPHY

- "The scientific examination of documents: Methods and Techniques", Ellen, D.M. (Ellis Horwood Limited Publishers Chichester)
- "Shandon Xylene Substitute in Document Examinations," by Gary Licht and Jerry Brown, Iowa Division of Criminal Investigation Laboratory, Des Moines, Paper presented at the 54th annual ASQDE conference, Washington D.C., 1996
- “Encyclopedia of Forensic Sciences”, Jay Siegel, Pekka Saukko, Second Edition, 2013

APPENDIX 5 – OVERVIEW PROCEDURE FOR RECOGNITION OF PRINTING TECHNIQUES

1. INTRODUCTION

Conventional printing is described as the process of transferring ink onto a substrate via a printing plate. The four classic printing technologies, namely letterpress, lithography, gravure and screen printing, use a physically stable, non-variable, image carrier.

Masterless digital printing does not use a non-variable image carrier (i.e. printing plate), but each printed copy is newly imaged onto the substrate. Electrophotography, ink jet, thermal transfer, thermal sublimation, photography or laser engraving can print one page after another with a variable content.

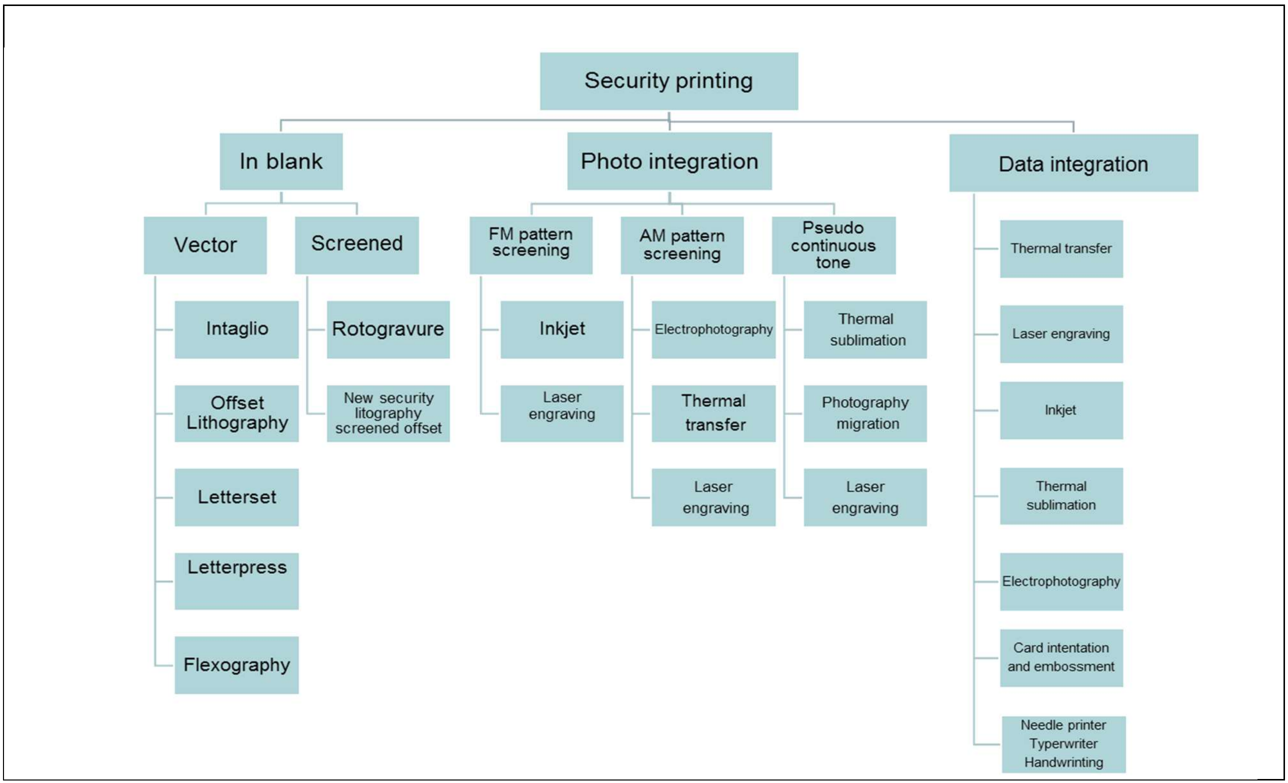
Independent of the printing technology – being it conventional or digital – any colour reproduction requires the image halftones to be composed by several full tone colours (usually cyan, magenta, yellow and black). This is realized by the process of colour separation for which conventional and digital printing require printing process dependent methods. Colour separation belongs to the prepress step of the printing process and is based on a subtractive respectively additive color mixing process.

Standard print media use a four-color mixing process (CMYK) with separate printing plates to print newspapers, books and magazines. The printing image in those cases is build up by individual microscopic screening dots. On the contrary, the security printing industry uses master plates with vector based full tone line work to print spot colors for passports, identity cards or driving licenses. This guarantees a wider colour gamut of the print products and a significant different microscopic printing image appearance so to differentiate from standard commercial screened print products and counterfeits.

Security documents generally are printed using specialized hiqh-quality printing equipment to reproduce backgrounds and non-variable data. The security document is individualized by adding a unique serial number by specialized numbering equipment, usually done by letter press technique. To personalize the document authorities integrate the bio-data with non-conventional printing technologies.

The most relevant technologies used by security printers to build documents in blank, to integrate the picture of the owner and the data entries is shown on figure 1.

Figure 1 Summary chart of security printing techniques



During forensic analysis it is vital to take into account whether we are verifying background images or variable data. As regard to variable data it is crucial to differentiate also between photographic data integration or individually made entries.

Recognition of and differentiating between various printing methods is of fundamental importance in determining a document's validity. As such, forgeries and altered documents are often revealed by the discrepancies in the printing methods used as compared to the authentic document.

The task of differentiating between printing methods is complex and requires specific knowledge of the interaction between the printing substrate (paper or plastic) and the ink. Document examiners must have continuous training in this field in order to cope with the rapid development of new reproduction technologies. Furthermore, it is advisable that document examiners seek and maintain contact with national security printers.

2. SCOPE

The main reason for determining a printing process is to be able to recognize forgeries and altered documents and to supply police with vital investigative information. The materials to be examined may include e.g. personal identity documents and cards, banknotes, stocks and bonds, drivers licenses, motorway tax stickers, tickets, stamps as well as any other documents of legal character.

In addition to documents, this type of examination can be extended to include product and name-brand forgeries.

3. PRINCIPLES

For this procedure, the printing techniques are divided up into the conventional printing processes (with a print master) and the digital printing processes (without an invariable physical printing plate). Be aware that conventional processes are mainly dedicated to background images and the digital printing processes to variable data.

3.1. Conventional Printing Processes

The main printing methods listed below have one thing in common: the elements to be printed (print patterns) are located on a permanent (mechanically stable) print master (printing plate). Using the same master in a printing press allows the reproduction of the same printing patterns in high-quality.

The four classic printing processes are:

- Letterpress (like Flexography): Elements to be printed are elevated.
- Gravure: Elements (screened dots or line work) to be printed are recessed.
- Lithography: Elements to be printed are more or less on the same level as the background, but are lipophilic (i.e. they attract the greasy printing ink).
- Screen printing: Elements to be printed are ink penetrable, i.e. the printing "plate" is a fine mesh.

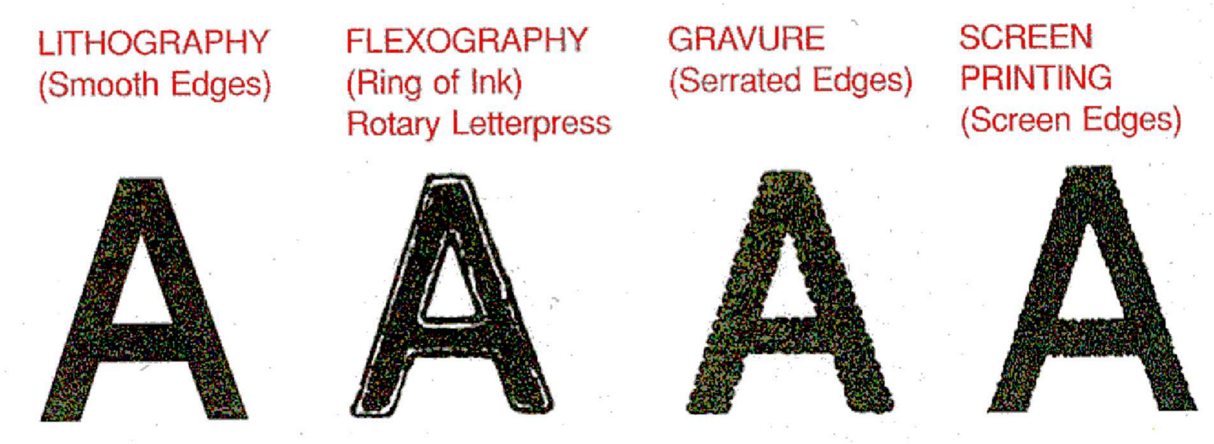


Figure 1

In addition to the four conventional printing methods listed here, a great number of other related subcategories exist, especially for small runs and office purposes.

3.2. Digital Processes

Since the middle of the 20th century, new processes have been developed in which the print form for each printed copy can be created individually and the "ink" (toner or inkjet ink) being directly transmitted to the substrate without a print form (e.g. inkjet) or a print intermediate (e.g. electrophotography). The processes like inkjet printing as an example are known today as "Non-Impact Processes" (NIP-Technologies).

The most important digital printing respectively reproduction processes are the technologies listed below:

- Electrophotography and other toner (electrostatic pigment charged)-based technologies.
- Inkjet technology (see method on the comparison of inkjet printers).
- Thermal printing technologies.
- Laser engraving.

These technologies also have many related subcategories.

In table 1, some common applications of the main printing techniques are compiled.

Table 1

Printing Process	**Common applications**
Dot Matrix	Home and office printing
Electrophotography	Home and office printing, medium volume industrial printing
- *Powder toner*	Low volume circulation products, posters, office printers and copiers
- *Liquid toner (Indigo)*	Medium volume circulation products, posters
Gravure	Industrial printing process
- Rotogravure	High circulation magazines, periodicals, mail-order catalogues, stamps, foils
- Intaglio	Security documents and banknotes, postal stamps
- Pad transfer or tampon printing	Non-paper surfaces of small size, e.g. gifts, tools, toys
Inkjet	Home and office printing as well as medium volume industrial printing
- Continuous	Dates on packaging, direct mailings, digital proofing
- Drop-on-demand	Office printers and copiers, large format, textiles
- Phase-change	Home and office printing
Letterpress (direct and indirect)	Security printing mainly nowadays
- Book printing	Books, numbering (numerator)
- Letterset	Small format jobs, business cards, forms, security documents

- Flexography	Packaging, labels, bags
Lithography(indirect, direct(rarely))	Graphical art
- Offset	Large and medium volume industrial printing for newspapers, magazines, posters, security documents
- Waterless offset	Security documents containing fine line structures
Thermal technologies	
- Direct thermal	Cash registers, tickets, barcodes, faxes
- Thermal mass transfer	Cards, large format, labels
- Dye Diffusion Thermal Transfer, D2T2	Cards, photo's, proofing, video printers
Thermography	Low volume printing of print products with special effects (raised print) like business cards
Laser engraving	Identity cards, driver's license
Photography	Photographs
Risography	Bureau duplication, copying and printing in low to medium quality
Screen Printing	Textiles, toys, fronts of radio's and TV's, packaging, large format posters, business cards but as well security printing
Stamp printing	Home use as well as application of stamps on official certificates

To enable proper forensic evaluation and to avoid false interpretations, an up-to-date reference sample collection of the various printing methods is indispensable.

Comparison of the questioned document with known samples must be carried out under the same conditions (same magnification, lighting, camera settings, etc.). Furthermore, the type of media, storage and age of the document must be taken into account, since these factors may contribute to individual characteristics.

Printing processes can normally be identified through optical examination techniques. Usually a magnifying glass and/or stereo microscope with various types of lighting is used:

- Direct light: many processes can be identified by looking at the document under direct light.
- Oblique light: for all raised and lowered print surfaces (e.g. intaglio printing).
- Transmitted light: for the examination of print alignment of double-sided print (Trans-view-register).

When identifying and differentiating the printing on security documents, it is necessary to use appropriate equipment for the examination of ultraviolet (UV) and infrared (IR) luminescence.

It is not always possible to identify the exact printing process used, despite fulfilling the minimal requirements of knowledge and equipment. However, certain processes can always be excluded. If there are no conclusive results, the print in question can at least be narrowed down to a few printing methods using the process of elimination.

It must be pointed out that in the more sophisticated forgeries multiple specific printing techniques may be applied to imitate other, more secure printing techniques.

To avoid mistakes in analyzing printing systems, it is of utmost importance to take into account the role of the substrate, the ink, the presence of continuous tone or screening (AM or FM halftoning), spatial tone value gradation, spot colors or multicolor printing and finally, whether we are looking at the background design or the variable data for personalization and individualization.

4. GLOSSARY

AM – In amplitude modulation halftoning the screening are arranged on a grid. There is a fixed number of dots on the orthogonal grid. Larger size dots are rendered to represent darker tonal values and smaller size dots are rendered to represent the lighter tonal values. Due to the fact that larger dots are used to represent darker tonal values, producing fine details in the darker areas in AM screening are less effective. Therefore AM tend to work best in mid tones. As the dots are equally spaced, AM screening tends to create rosettes patterns that are visible to the naked eye. As dots are equally spaced, Moiré patterns can easily get visible to the naked eye. To minimize the Moirés effect, dots are designed to be placed at certain angles. The most common angle for a CMYK 4 color process is C(75°), M(15°), Y(0°), K(45°).

FM – In frequency modulation screening, the half tone dots are fixed in size. However, unlike AM screening, the dots in FM screening are arranged stochastically or randomly according to the tone value that would like to be produced. Darker tonal values are produced by placing more dots (higher dot frequency) in the region and lighter tonal values are produced by placing less dots (lower dot frequency) in the region. FM technologies amplifies dot gain. It was hard to make the transfer from film to plate during the plate making process before the introduction of CtP (Computer-to-Plate) technology. Mid-tones are harder to control in terms of how the dots should cluster. When dots connect or overlap, noise or mottle can occur. Unlike AM dots, by their nature, FM microdots on press resist added ink densities. As a result, it is difficult to make color or tonal adjustments. Since FM screening utilize very small dots (usually from10 to 20 microns) to produce the images, very fine details are possible. As dots are randomly placed, this eliminates the screen angle problem, therefore eliminating the Moirés and rosettes patterns. FM screening is able to create a wider gamut than AM screening

XM– cross modulated screening or hybrid screening uses FM screen in the highlighted and shadow areas and AM screen in the mid-tones. XM applies special technology to smoothly transition from one screen to the other. XM screens combine the best performance characteristics of both AM & FM

5. CROSS REFERENCES

- The examination of inkjet printed documents
- NIR absorption and reflection examination of documents
- Application of luminescence to the examination of document.
- Ink analysis by TLC
- Toner examination
- Stamp and stamp impressions

6. PRESERVATION AND HANDLING OF ITEMS

Depending on the other forensic examinations requested for the document, appropriate precautionary measures must be taken to preserve the evidence and avoid contamination. This usually means wearing protective gloves when handling the document in question.

Fingerprint detection should be performed after the examination of printing techniques.

7. EQUIPMENT/INSTRUMENTATION/OPERATING CONDITIONS

- Magnifying glass or stereo microscope and light microscope
- Various light sources for direct, oblique and transmitted light
- Equipment for detecting luminescence in the visual and infrared.
- Ultraviolet light sources in the 366 nm and 254 nm range
- Scalpel
- Needle
- Screen measuring devise
- Collection of various samples of the different printing methods
- Magnetic reading device for analysis of magnetic properties
- Flatbed scanner

8. HEALTH AND SAFETY

Short-wave UV-light (254 nm) is extremely dangerous to the eyes and skin and may cause cancer. Avoid using a short-UV excitation source if possible; otherwise wear protective clothing and eyewear.

Protective eyewear must also be used when working with powerful light sources such as Lasers and Xenon lamps in an exposed environment.

In case a document that has been treated with Ninhydrin for dactyloscopic analysis protective gloves need to be worn.

This method does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

9. PREPARATION AND CALIBRATION OF EQUIPMENT AND REAGENTS

Check the manual of the equipment to see if a period of stabilization is necessary and how and when a calibration is required.

10. PROCEDURE

To ensure a replicable/defendable examination, all steps should be performed when applicable and noted when appropriate. At various points in these procedures, determining that a particular feature is not present in an example (reference) or that the sample to be examined lacks quality or comparability can indicate that the examiner should discontinue or limit the procedures. It is at the discretion of the examiner to discontinue the procedure at that point and report accordingly, or to continue with the applicable procedures to the extent possible. The reason for such a decision should be documented.

The examiner should as well check whether he/she might have a potential conflict of interest before analyzing the document to guarantee an unbiased and objective analysis.

It is required to analyze the document to determine which examinations are applicable and in which sequence and which are not.

10.1. Determination of printing process

The printing process is determined in the following manner:

- Examine the document (printing and media) as a whole, without use of the microscope.
- Examine the document for print-specific elements and ink/toner deposit characteristics by means of a microscope (observation of the edge zones and surface of the print), see p 10.2 and 10.3 . In 10.2 and 10.3 listed features and images are media and apparatus dependent and may not be apparent in all samples of a certain printing techniques.
- Examine the document in different places to determine if more than one printing techniques has been used.
- Depending on the questions asked, the unprinted zones of the document should also undergo closer examination e.g. to detect toner particles.
- When using a reference print sample, attention should be given to selecting a substrate that is most like the substrate of the document in question.
- To check for luminescent elements (e.g. security print or paper) an additional inspection using UV and IR-lighting should be performed.

- When authentic reference material exists in addition to the forgery, a comparison between real and forged shall always be made.

10.2. Conventional Printing Processes

10.2.1. Letterpress

Letterpress (direct and indirect) is used mainly for serial numbering by security printers, although you can find background prints produced in letterpress in some documents (e.g. certificates).

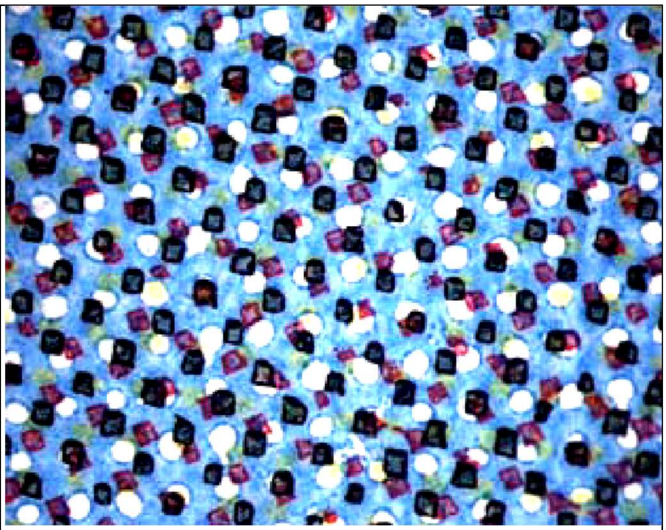
LETTERPRESS numbering

A conventional technology that uses relief printing masters and pressure to transfere the ink to the substrate. In security printing this technique is used for introducing sequential numbering by employing special numbering boxes.

The numbering process is a special letterpress method (with the same print-specific characteristics), whereby the distance between the numbers always remains the same, regardless of the character's width which is due to the specific numbering mechanism used.

Because substrates are commonly softer than the letterpress plates, indentation on front and embossment from the reverse appears (e.g. in passport booklets). The ink is rather thick and viscous squashing to the letter edges mostly in direction of the paper movement. Ink leaking into the printed areas are also found under magnification. Well defined corners help to differentiate numbering from flexography. Concentrated ink deposits or a so-called "dot-squeeze" or "halo-effect" at the edges of the printed symbols can be observed.	

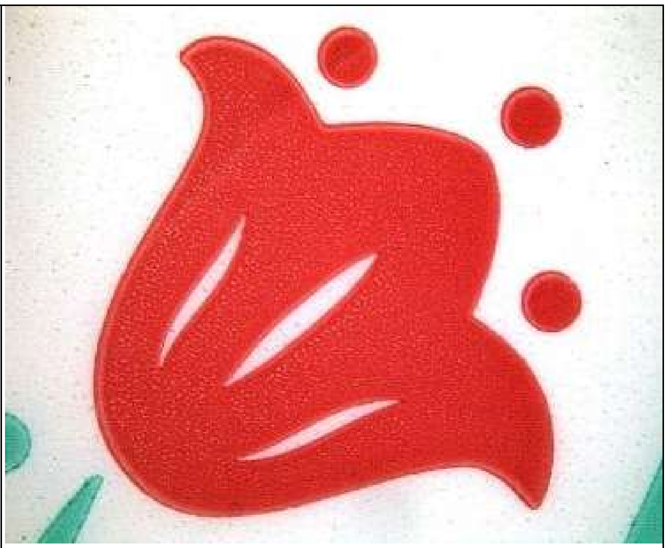
BOOK PRINTING

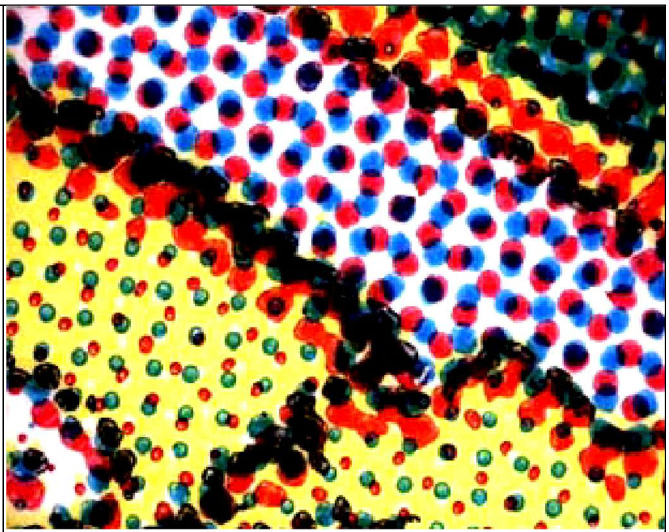
There is a slight indentation on front and embossment from the reverse. The ink is rather thick and viscous squashing to the edges. Concentrated ink deposits or a so-called “dot-squeeze” or “halo-effect” at the edges of the printed symbols are present also in case of AM print elements.	 *AM letterpress*

FLEXOGRAPHY or FLEXOGRAPHIC PRINTING

Method of rotary letterpress printing, using flexible rubber plates and (rapid drying) fluid inks. Used mainly for packaging.

Flexography employs a rubber plate in a letterpress machine. The master is softer than the polymer used in letterset. Used with a variety of non-paper substrates, and sometimes registration problems between the printing plates can occur.

Flexography shows similar characteristics like dry offset, but paper embossment and a more pronounced squash effect may occur.	 Linear master plate

	 AM master plate for colour reproduction

STAMPING

In principle, stamps (rubber or polymer) are some sort of flexographic masters.

Official stamps are often manufactured using rubber, photo-polymer or metal and will often have a very specific purpose.

LETTERSET, DRY OFFSET or INDIRECT LETTERPRESS

A conventional technology that uses a letterpress plate in an offset machine so to image the transfer belt.

Letterset is a printing system that combine a letterpress plate (a hard, polymeric master) and an offset machine. In letterset the image of the raised plate is transferred to the paper via an intermediate carrier (a cylinder covered with a blanket). Since this process does not require the lipophile / lipophobic properties of the printing plate the process is named “dry offset”.

Since the printing image is transferred from the printing plate to a rubber blanket and subsequently from there transferred to the printing substrate you will not find substrate embossment. Under the microscope, a squash effect can be identified, however they appear more like a kind of border around the print image and no additional ink build up can be observed with the stereo microscope. Edges in corners appear slightly rounded, but no so much than in flexography.	

10.2.2. Gravure

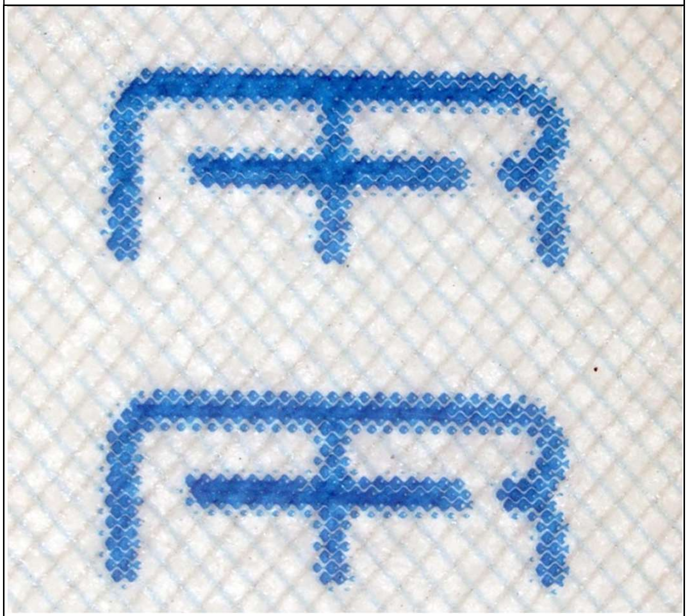
Gravure printing is a very good illustration printing technology, achieving high quality due to its near continuous tone.

In conventional gravure, the printing surface is made up of cells that are the same area but vary in depth, with the deepest ones representing the darker areas of the subject and carrying the most ink, and shallower ones corresponding to the lighter areas of the subject.

ROTOGRAVURE (GRAVURE)

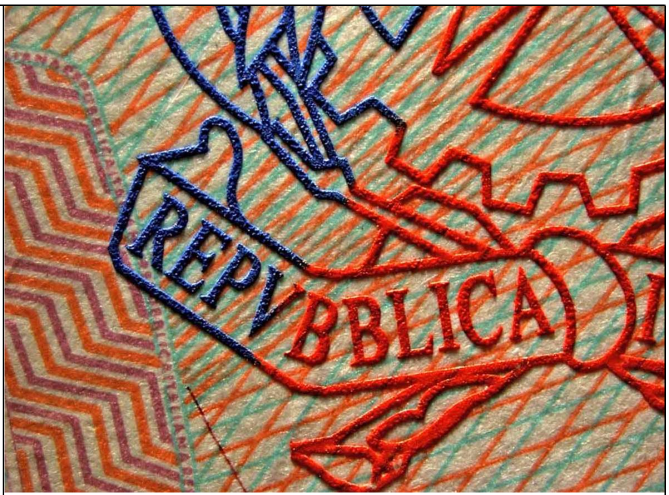
A conventional printing technique in which the printing elements of the master are recessed. The gravure cylinder is covered with low viscosity ink and then passed under a doctor blade which removes all the excessive ink, leaving ink only in the recesses. The printing material is pressed onto the cylinder surface, taking up the ink from the recesses. Gravure printing is usually used for long print runs such as weekly magazines of general interest and mail order catalogues.

In security documents you can find it in laminates.

<table>
<tr><td rowspan="2">Gravure has a few typical features that help us to identify it under magnification: square or hexagonal screen cells, serrated (saw-tooth) or jagged edges, screened text, doctor blade streaks (thin vertical streaks of ink), speckles (white spots when ink fails to come out of cell)</td><td></td></tr>
<tr><td></td></tr>
</table>

INTAGLIO

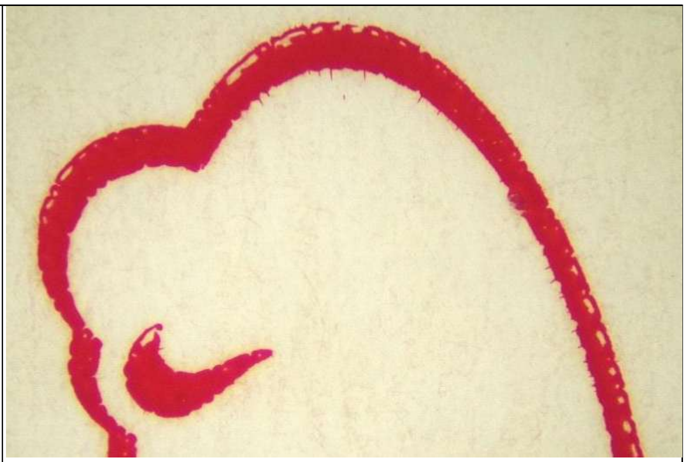
A form of gravure printing employing a steel plate with minute engraved wells. Intaglio is most often used in security printing to make a tangible raised printing surface.

<table>
<tr>
<td>Raised surface, tactile, very fine detail and line structures. Due to the large forces applied by the printing cylinder, the edges contain a feather effect and the substrate is additionally embossed on the back. Side light is necessary to extract the shades that offer the three dimensional appearance.</td>
<td>

</td>
</tr>
</table>

PAD or TAMPON PRINTING

An indirect gravure method where a silicon pad picks up the ink from the recessed image areas in the master and transfers it to the object to be printed.

Since the printing image is transferred from the master to a silicon pad and subsequently from there transferred to the printing substrate (paper) you will not find substrate embossment. Outside of the image fiber like splashes occur. However they appear more like a kind of border around the print image. Speckleses occur (white spots), when ink fails to come out of cell.	 

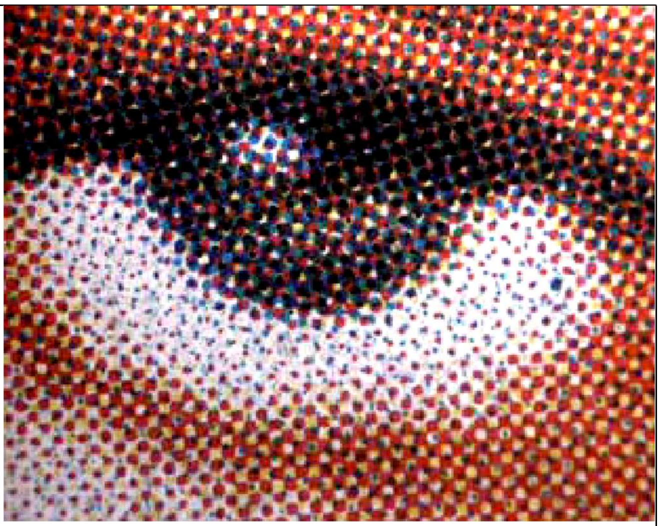
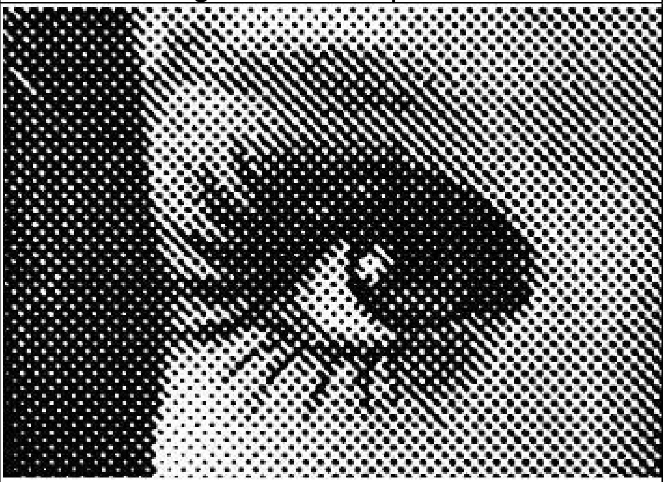
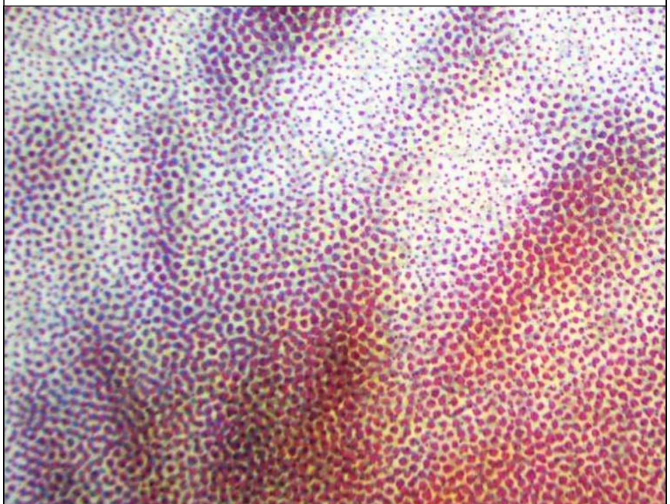
10.2.3. Lithography

Lithography or Lithographic printing is a conventional art craft printing technique using a planographic plate to transfer ink to the substrate. Lithography takes advantage of the chemical repulsion between water and grease to separate the printing from the non-printing areas. The printing design is greasy and ink-receptive (lipophile), whereas the rest of the stone (stone still in use for graphic arts) or plate is dampened with a solution (water and other components) to make it ink repellent (lipophob).

OFFSET LITHOGRAPHY

A lithographic method where the design is first printed on a rubber covered cylinder before being transferred to the substrate. One reason for using a rubber covered cylinder is to prevent the delicate lithographic plate from coming into contact with the more abrasive paper surface, which would cause significant wear and tear on the plate during the run. Another advantage of the offset principle is that less water comes into contact with the paper than in direct lithography.

Although offset lithography (not screening-spot color) is not an exclusive process of security producers, what it is unique in security makers is the high quality (in particular in terms of register) of its results due to the high-tech machinery involved. The master plates can be AM or FM rasterized.

Distinguishing characteristics are plane images and well defined edges. The layer of ink has a silky appearance and it penetrates the paper except when a quick drying method is applied (e.g. UV-drying).	 AM halftoning for colour reproduction  One colour AM offset 

	FM halftoning for colour reproduction  One colour FM offset

WATERLESS OFFSET

Waterless offset is an offset lithographic process that eliminates the water or dampening system used in conventional offset printing. The master surface is ink repellent in the non-imaged area due to a silicon layer. The ink-receptive areas are created by ablating away the silicone layer leaving a slightly recessed plate that is lipophilic. Waterless offset inks have a higher tack and viscosity and are generally stiffer than conventional offset inks. The image surface of a waterless plate is recessed, allowing the plate to carry a greater volume of ink than a conventional plate does.

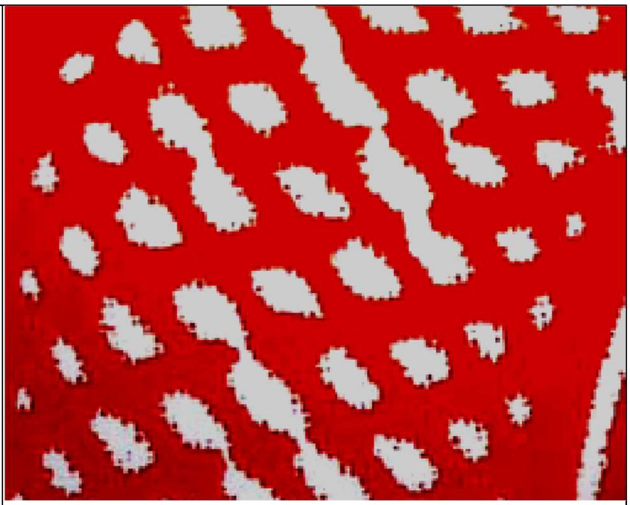
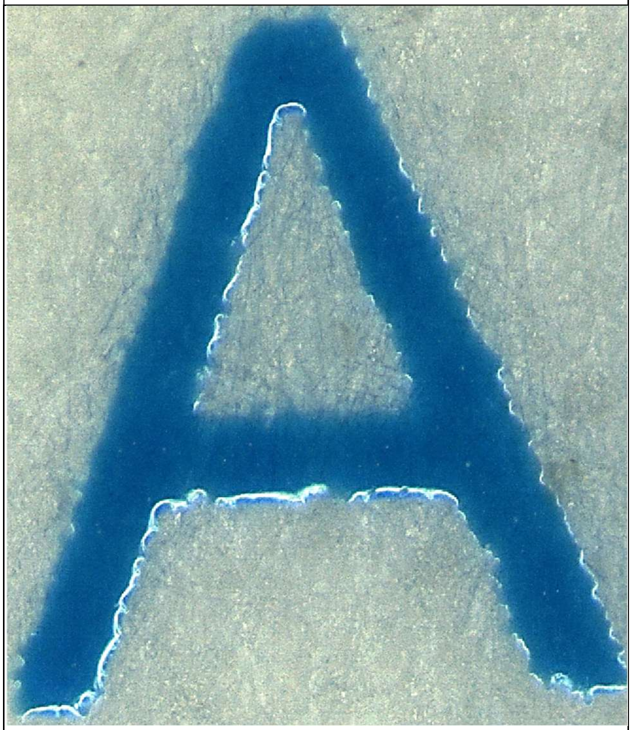
It is very difficult to differentiate the printouts from offset.

10.2.4. Screen printing

SCREEN PROCESS PRINTING

Screen printing is a conventional push-through process in which the ink is transferred from the master to the substrate through the unblocked areas of a metal or plastic screen by means of a squeegee (doctor blade). Screen printing is used in the production of coloured posters, show cards, printed circuits, CD's etc., but as well in the security printing industry. This technique is used in security printing for application of special effect inks since here a thicker ink layer is required to allow the rather big pigments to align properly.

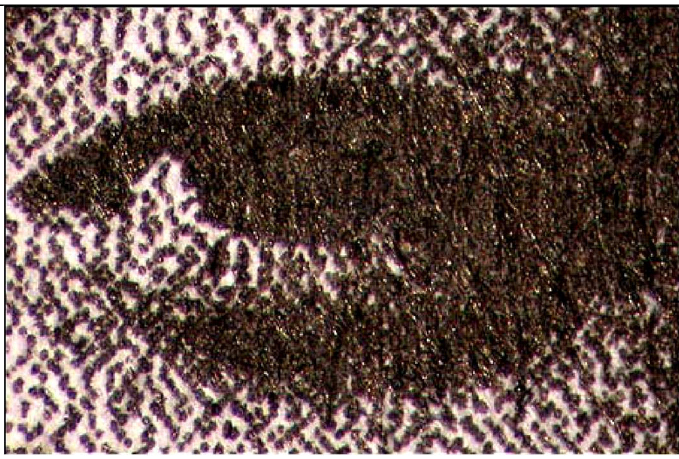
Silkscreen uses a fine mesh made of natural silk, plastic, or metal threads as a master plate. The non-printing elements of the mesh are blocked by a coating. The screen plate is covered with ink, and a squeegee is passed over it so to push the ink through the mesh onto the underlying print substrate.

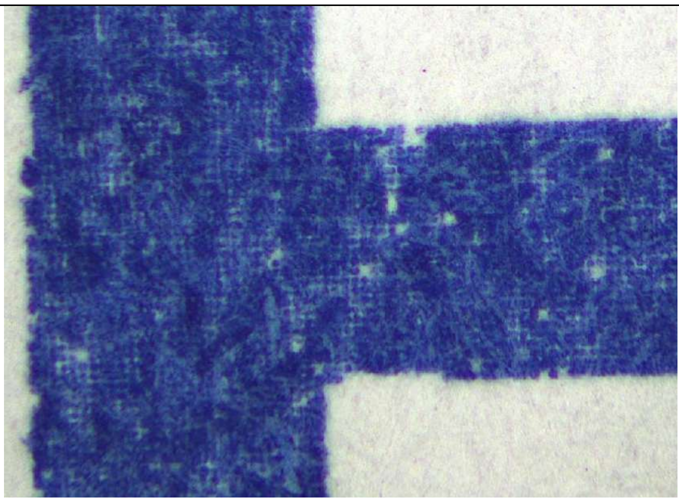
<table>
<tr>
<td rowspan="2">Due to the screen structure of the mesh, notches could be appear in the edges of the lines (sawtooth effect) and in many cases the ink layer can be rather thick. Dependent of the mesh and the ink, it may be possible to recognize mesh pattern or screening on the printed area. It should be noted that the sawtooth effect can be missing and the amount of print transferred can be very small.</td>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</table>

RISOGRAPHY

A non-impact technology that combines the push-through printing process principle with the thermal perforation of a master film. The binary information from a scan or digital file is used to control a thermal print head with an array of heating elements that melt and thus perforate a polyethylene (PE) layer in which the “master” consists. Only the holes in the PE allow the ink to pass, by which means an image is formed on the paper.

In “Risography”, binary, round dots with sharp edges but irregular shapes and sizes, are found under magnification. Different dot patterns (regular or irregular screen) are possible, although halftoning leads to poor image quality. Very dark large areas may contain some noise. Mostly monochrome prints, but the ideal approach is to use a limited amount of two or three colours.	



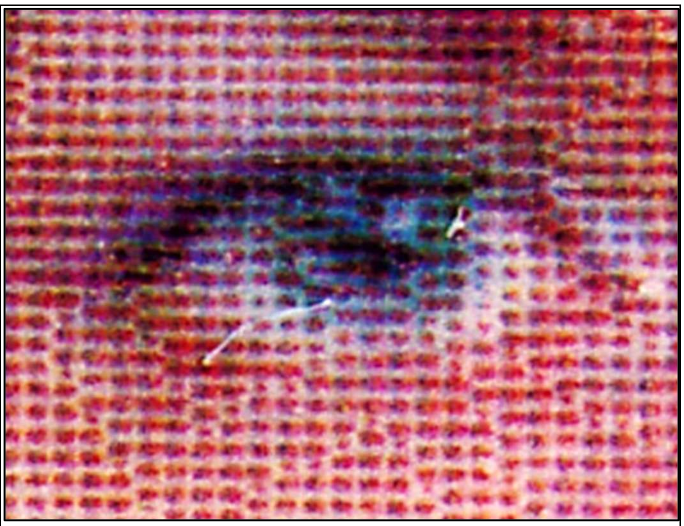
10.3. Digital Processes

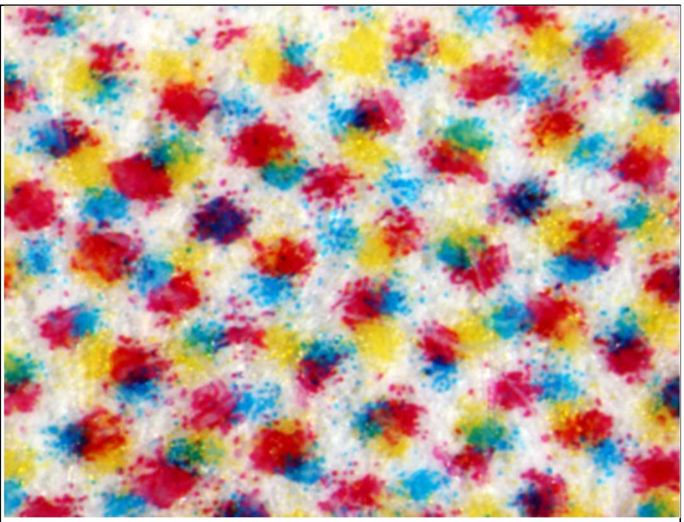
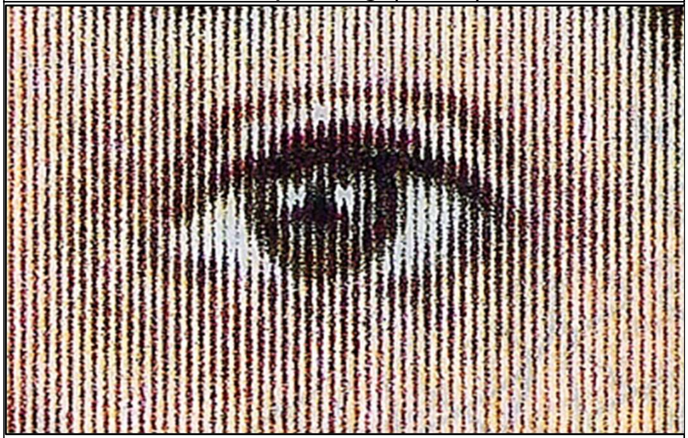
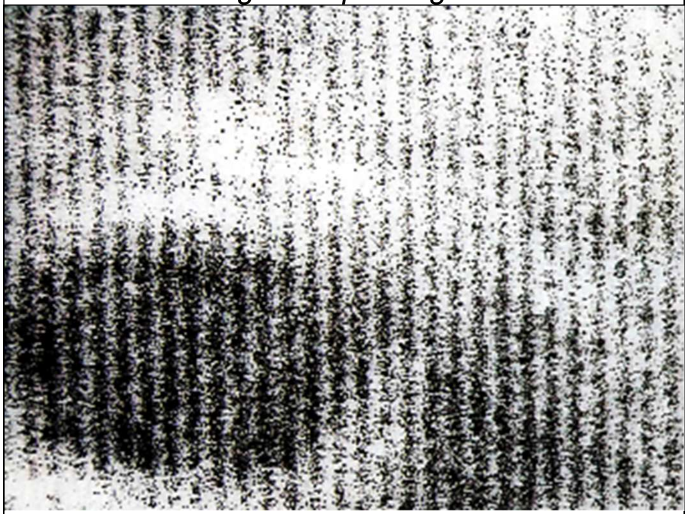
10.3.1. Electrophotography and other toner based technologies

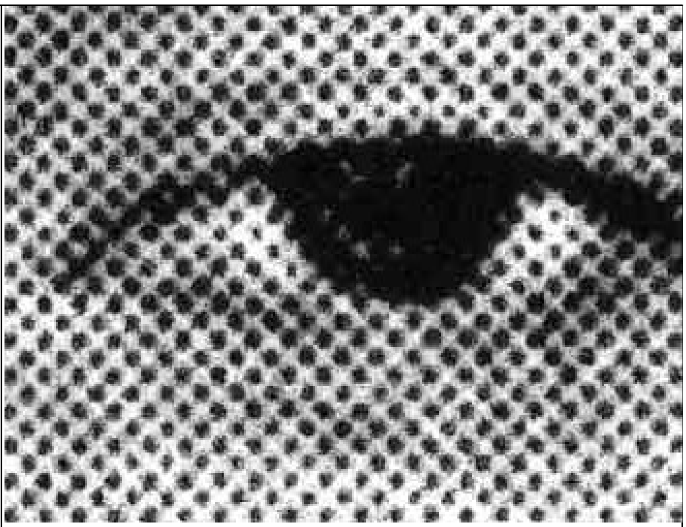
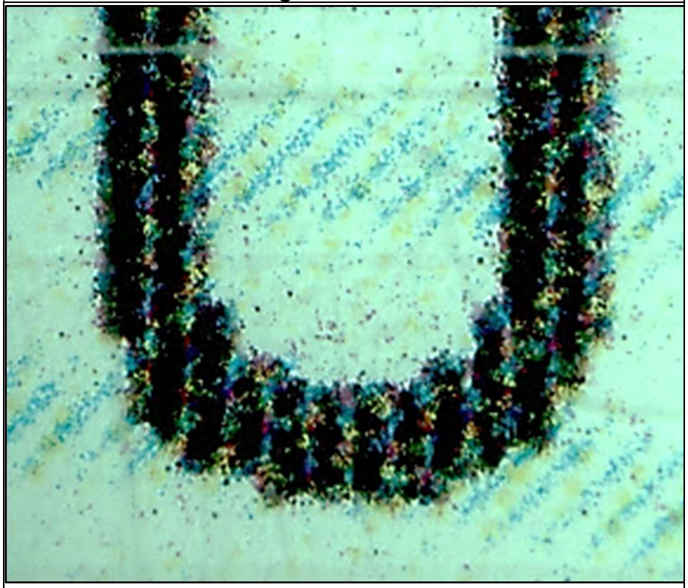
Electrophotography or xerography is a non-impact technology based on the transference of an electrostatic latent image created in a photoconductive material to the substrate. This image is then developed using toner that is fused afterwards to the medium. This process is widely used in copiers and laser printers.

Electrophotography spread pigments in different ways: in continuous tone and halftoning for black and white machines, and in a linear and halftone screening for color devices. Toner deposits can often be easily removed with a scalpel.

POWDER TONER

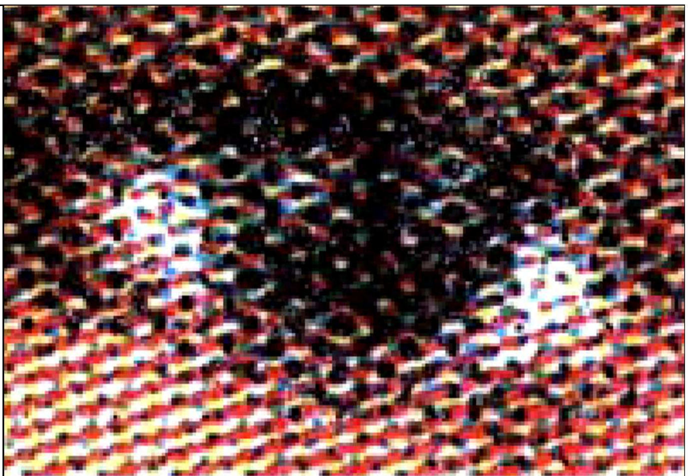
Printed areas have a glossy surface that differs from that of the substrate. Particles of dust will be found in the blank areas of the paper, a singularity of the fixing process that you will never see in other printing techniques under magnification. A hot laminated foil over the toner deposit can often hide the characteristics of the toner print and can lead to wrong conclusions. Raised surface, glossy, granular appearance	 *AM color halftone printing*

	 *AM color halftone printing (detail)*
	 *Linear screening color printing*
	 *B&W linear halftoning*

	 *B&W AM halftoning*
	 *AM color screening for entries*

	 *B&W continuous tone for entries*

LIQUID TONER (HP Indigo)

Liquid toner (e-Ink) is used in hybrid printing systems such as HP Indigo, an imprinting unit that combines liquid charged “toner” with belt image transfer unit as being common in offset machines. The e-Ink ”toner” forms a very thin homogeneous layer film on top of the paper fibres and the dot edges are very uniform and sharp At high magnification, toner aggregates may be visible at the edges of black dots in Indigo prints.	 *AM screening*

<table>
<tr><td></td><td>
AM screening for entries</td></tr>
</table>

10.3.2. Inkjet technology

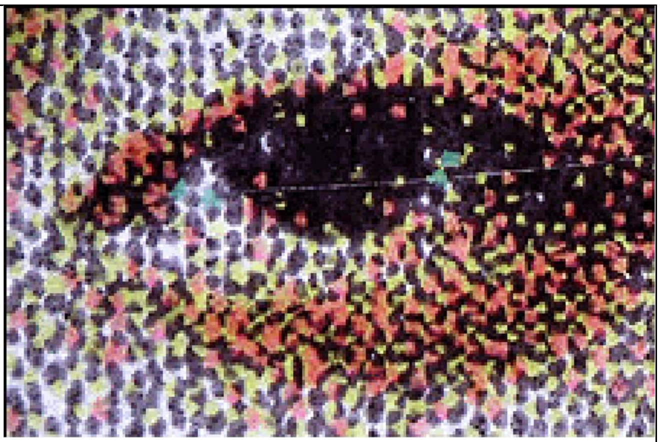
Inkjet printing is a non-impact printing method in which images or characters are formed by projecting droplets of ink from a nozzle onto a substrate.

<table>
<tr><td>The inkjet process is a non-impact / computer to print technology, in which ink is sprayed directly from very fine nozzles to the substrate. Because the drying process includes the spreading and penetration of drops into the paper (with the exception of solid ink) high resolution inkjet printing offers a print quality that is close to real continuous tone as in photography.
Continuous flux technology leaves, depending on type of application, curved lines, low resolution (for e.g. use-before-dates on packaging) and variable dot size under magnification. Regular dot patterns are possible for e.g. proofing or fine arts reproduction. Usually most inkjet printers use CMYK tones whilst the black tone can be pigmented, however there is as well the possibility to build the image only</td><td>
Text entries in colour</td></tr>
</table>

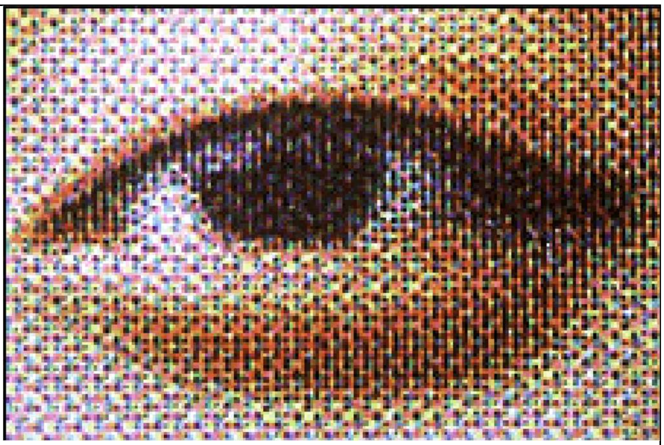
with CMY. Some high-quality inkjet printers offer as well the use of spot colours. Moreover, printers exist that use different dot sizes in the same machine.	 Text entries in black

PHASE CHANGE INK JET

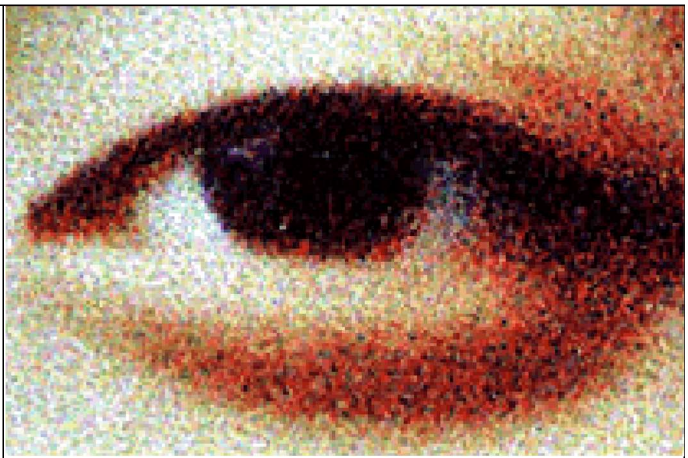
It is a form of drop-on-demand inkjet printing. Solid ink, consisting mainly of a transparent mixture of synthetic waxes, is used in phase change printers. It is purchased in the form of a pellet or stick, which is inserted into the printhead, where it is partly heated so as to form a liquid. This hot wax is then ejected by a piezoelectric printhead onto the medium. As the droplet hits the substrate, it freezes immediately, without allowing much of its substance to penetrate the surface of the paper.

Brilliant, saturated colours, dots have sharp edges that do not bleed or feather and lie on top of the paper fibres The image consists of round shiny dots that form a separate layer on top of the substrate. In general, a continuous tone effect is not achieved. Ink lies on the surface and has a waxy feeling. Solid inkjet gives a slightly tactile print.	

CONTINUOUS INK JET

Depending on type of application: Curved lines, low resolution Variable dots size and different, but always regular dot pattern possible	

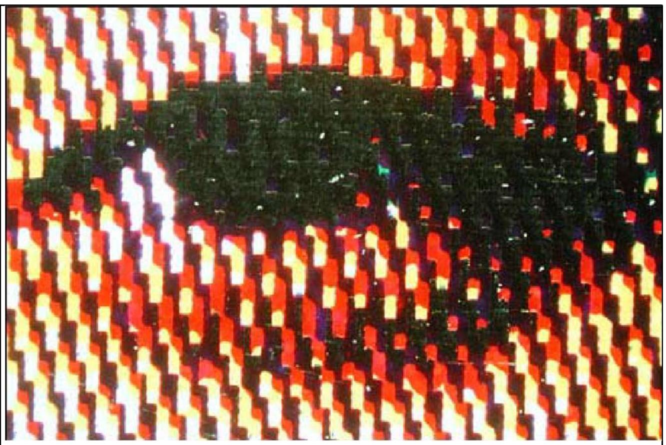
DROP-ON-DEMAND (piezoelectric, thermal inkjet)

High resolution, variable-size dots are possible.	

10.3.3. Thermal printing technologies

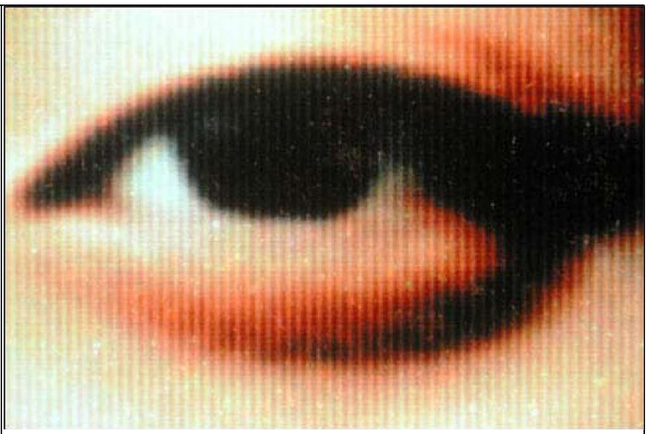
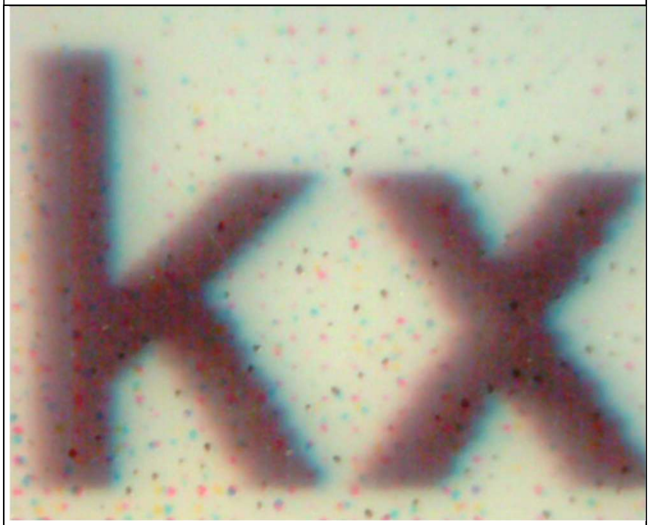
THERMAL MASS TRANSFER (D1T2)

The application of heat and pressure from a marking head at discrete points to a thin polycarbonate ribbon with a waxy coating on one side causes the pigment to transfer to the receiving medium. The resolution varies from less than 300 up to 600 dpi. The technique is also called: Direct Thermal Transfer (D1T2), thermal wax transfer, thermal transfer, thermal fusion.

Ink lines on top of medium and has a waxy texture, binary (either printing or non-printing) print with brilliant, saturated colours. Dots have sharp edges. In general, a continuous tone effect is not achieved with D1T2 printing. The shape of the tip of the heating stylus and the image forming pattern can usually be seen under magnification.	 

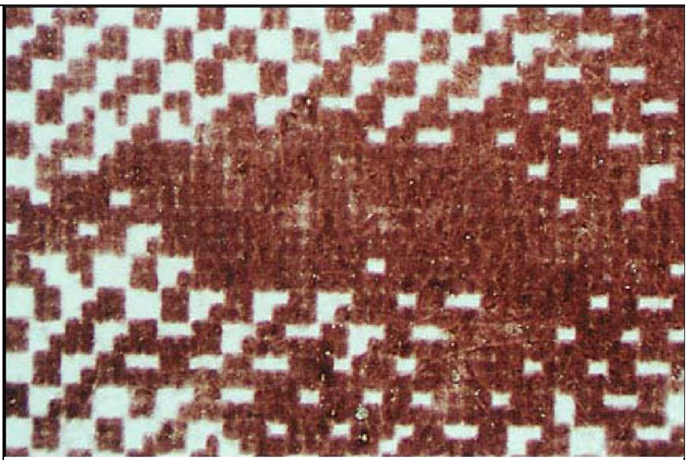
DYE DIFFUSION THERMAL TRANSFER or THERMAL SUBLIMATION (D2T2)

This thermal sub-technology, employs a set of ribbons that is made up out of several panels. Each panel is composed out of dyes and resins that are transferred to the receiver sheet by the application of heat and pressure from a stylus at a discrete point. The dye will sublimate and migrate to the substrate, where it will be chemically bound into a receptor coating. The technique is also called: Thermal Dye Sublimation, Dye Sub or Thermal Dye Transfer (TDT)

Solid ink is heated until its vaporization. The printing material must be treated with a special coating into which the ink penetrates by means of diffusion. Continuous tone, photographic quality, to the naked eye indistinguishable from photographic prints. Under magnification a regular grid of faint, diffuse-edged squares or lines can be detected. Color misalignment of the Y, M and C dyes, visible under slight magnification, is common. Blank spots caused by dust between medium and ribbon during printing may be present.	 

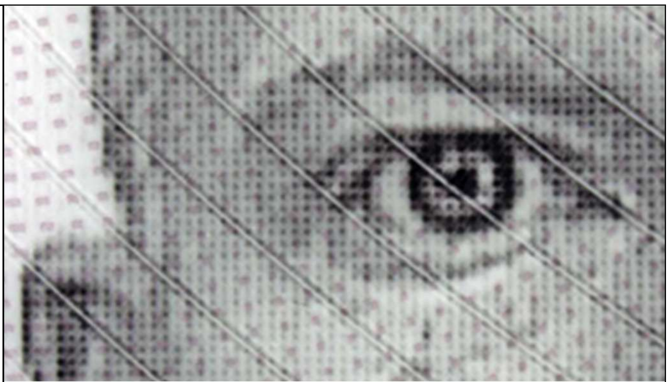
DIRECT THERMAL

This thermal sub-technology employs a head of heating stylus to print in a binary mode low quality jobs on thermal sensitive paper. The pin-like head of the tip of the heating can usually be seen under magnification.

Thermal sensitive paper (coated paper) is required for this printing method, usually a low quality binary (either black or white) print is characteristic. Nevertheless, very sharp lines can be rendered. The pin-like head of the tip of the heating stylus can usually be seen under magnification. Paper fibers are barely visible through the coating.	

10.3.4. Laser engraving

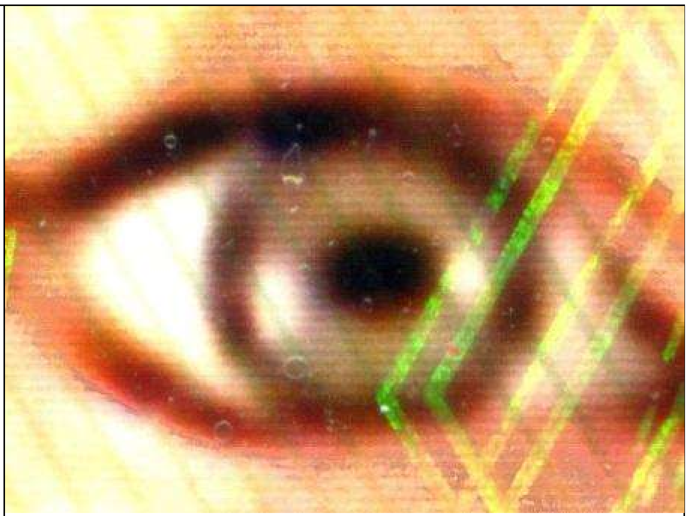
Laser engraving is a non-impact printing method where the image is formed by a controlled laser beam that penetrates a prepared plastic substrate. The particles in some layers of the substrate absorb the laser energy and turn to a darker color by carbonization.

Spreading of polymers has led the laser engraving to be the most common among personalization techniques of the security card industry. By using laser engraving, data entries and photos become a part of the physical structure of the card, making alteration impossible without leaving traces. By variably focusing a laser beam onto the sensitive layer of a polymer and by manipulating the laser power, a wide array of screening on the substrate can be realized. Laser engraving allows the creation of dots and structures of any shape and tactile effects, making holes or blisters that add security to personalization. By chance, the raised structures created in the lamination process interact with the laser beam leaving singular traces, which are impossible to replicate with other technologies.	

10.4. Other techniques

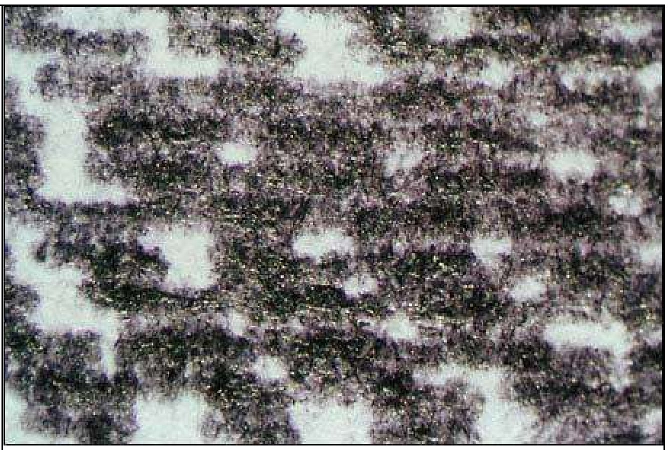
10.4.1. Photography

Photography is a method of obtaining an image of an object by the action of light onto a sensitized layer.

Some governments use a photographic process for photo and variable data integration. True continuous tone reproduction occurs, due to diffuse "clouds" of dyes migrating into the upper layers of the photographic sensitive medium. A photographic reproduction can easily be mistaken for a thermal sublimation print due to its blurred appearance at microscopic view, and it´s almost continuous tone.	

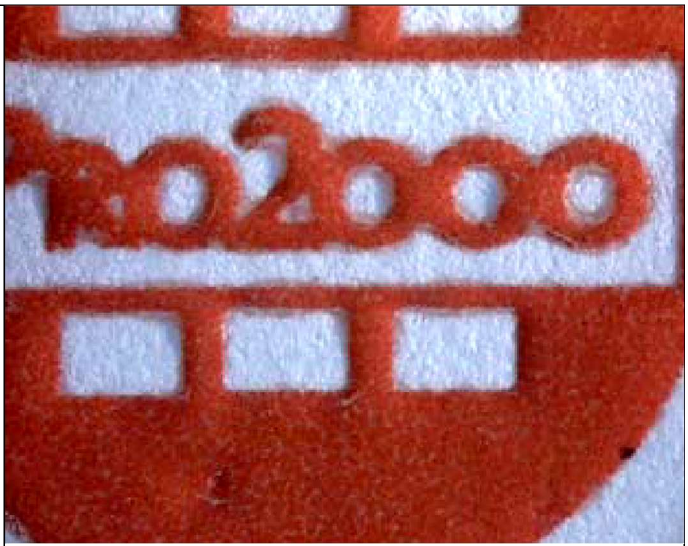
10.4.2. Dot matrix

This printing process produces characters and images that are made up of a regular array of closely printed dots, transferring ink to the paper by striking pins against an ink ribbon. Unique to dot matrix printers in the realm of digital printing is their ability to print multi-page documents or forms, e.g. making carbon copies, by using the impact of the pins against the paper. The number of pins in the printhead (9-24) determines the quality of the image.

Low resolution, mostly text. The dots that make up the image are easily seen with the naked eye. Dots are often incident with a slight indentation in the paper caused by the impact of the printing stylus. The paper fibers can be seen through the ink.	

10.4.3. Thermographic printing

Thermographic printing or thermography is an art craft, raised printing technique, based on the combination of letterpress or offset printing with a special ink and a resinous powder. Just the substrate is printed, and the ink is still wet, the surface is dusted with powder particles that adhere to it. The sheets are then baked what causes the powder particles to fuse with the ink, giving them a raised effect that simulate steel-die or copperplate engraving. Used principally for letterheads, business cards, envelopes, announcement and greeting cards and folders, but also managed by fraudsters to simulate tactile effect of intaglio.

Raised image, thick and glossy ink film containing tiny bubbles. Transparent rim around the edges.	

11. RECORDING AND INTERPRETATION OF RESULTS

Whenever possible, a photo documentation of all the relevant print-specific characteristics and other characteristics of the questioned document should be included in the expert report. Preferably, the photo documentation in the case of a forgery should illustrate the differences between the counterfeit and the genuine document.

12. QUALITY ASSURANCE AND COMPETENCY

The analysis should undergo a peer review, thus an independent examiner should check all results and conclusions that are open to interpretation.

To be able to make examinations of print techniques (e.g. in the context of identity documents, banknotes, stocks and bonds etc.), it is necessary to have knowledge in the areas defined in the Skills and Knowledge Base document.

Special emphasis should be given to the document examiner's on-going training (expert literature, participation in seminars, courses, symposiums, etc.) due to rapid technological advances especially in the area of non-impact-printing processes.

13. BIBLIOGRAPHY

- Helmut Kipphan, Handbuch der Printmedien or Handbook of Printmedia, Springerverlag, 2000
- The Printer, Magazine „Druck & Medien“ Magazine, Druck-Medien Verlag GmbH, D-Waiblingen, Ron Morice
- Adams, J.M., Faux, D.D., Rieber, L.J., “Printing Technology, 4th Edition”, Delmar Publishers, 1996
- David Bann, The all new Printing Production Handbook, RotoVision SA, 2006

- Richard D. Warner, Richard M. Adams II “Introduction to Security printing” , Printing Industries Press, 2016
- Fons van der Linden “ DuMont's Handbuch der grafischen Techniken manuelle u. maschinelle Druckverfahren”, Du Mont, Köln , 1986
- Michael Nitsche “Polygraph Dictionary of the graphic Arts and Communications Technology” German-English, Polygraph Verlag, Bielefeld, 1999
- Harald Johnson “Mastering Digital Printing”, Thomson Course Technology, Boston, 2005
- Michael Barnard “The Print and Production Manual”, PIRA international, Leatherhead, 1998
- Martin C. Jürgens, The Digital Print Identification and Preservation. The Getty conservation Institute, Los Angeles, 2009

APPENDIX 6 – OVERVIEW PROCEDURE FOR TONER EXAMINATION

1. INTRODUCTION

The classification and identification of photocopiers or laser printers presents particular problems for the document examiner. While comparison of defect marks serves to identify copies produced on an individual office copy machine, it is often necessary to eliminate large numbers of machines as possible sources before commencing this detailed examination. The examination and differentiation of toners offers an effective means of achieving this elimination.

In cases where the question is, if text on a document is partially added by a secondary printing process, there is often no need of toner identification. Toner differentiation analysis (e.g. questioned paragraph versus text that is not in question), has to be performed for manipulation evidence.

Toner examination can be performed using multiple techniques, such macroscopic and microscopic examination, physical examination and chemical examination (FTIR, Raman spectroscopy, microanalysis-X, etc.).

2. SCOPE

This procedure will cover only the analysis of different kinds of toner. The examination of manufactured identifying characteristics such as grip marks, roller marks and acquired identifying characteristics such trash marks or repetitive defects will be discussed elsewhere. In this procedure the term “document” refers to a document coming from a photocopier, a laser printer or a fax machine using toner.

If there are no visible identifying characteristics, a physical and/or chemical analysis of the toner may provide some information. The scope of this procedure is to compare the toner on a questioned document (or part of it) to that on a known source (another document or a printed document from a given photocopier or laser printer) to determine if the questioned document (or the questioned paragraph) comes from a different source.

The identification of a brand or model of an office machine based solely on the analysis of the toner remains possible in some cases but it is a very difficult task and is beyond the scope of this procedure.

3. PRINCIPLES

Toner can be distinguished into 3 general classes: single-component, dual-component and liquid toners.

With regard to single-component systems, "toner" refers to the pigmented particles used to visualise the latent image which are subsequently fused to the paper where they take on the appearance of ink printing.

In dual-component systems, "toner" is used to describe both the pigmented particles themselves and, on other occasions, the combined mix of pigmented particles and carrier particles that form the dual-component system.

Liquid toners consist of a carrier liquid containing very small toner particles (1-3 μm). The carrier liquid is removed from the developed image by evaporation.

Forensic examination of toner is mainly concerned with what is present on the document "i.e." with the pigmented or dyed particles, after fusion onto the paper, rather than with the carrier. However, in some machines carrier and pigment are not fully separated in the copier mechanism and some carrier particles are transferred with toner to the document where they can be detected during analysis.

DeCopier Technologies, Inc., of Framingham, MA, has developed an office paper DeCopier that uses a thermo-chemical process to soften toner and loosen its bond with paper. The toner is then brushed away and the sheet dried. The result is a "clean" sheet of paper that is ready to be reused. DeCopier Technologies, Inc. reports that this process will not only work on documents prepared by a photocopy machine or laser printer, but on transparencies, facsimiles, and other documents with toner components/entries. DeCopier Technologies' ability to successfully remove toner from paper is currently limited to relatively few types of toner.

If DeCopier technology is used to alter or destroy a document, the document examiner may not have the ability to restore the lost information, nor be able to conclude that a document has been altered. Forensic document examiners should be aware of the work of DeCopier Technologies, Inc. and keep abreast of any advances they make in the future.

4. GLOSSARY

Dry toner - Minute, dry particles of binding agents, additives and carbon black (or other dyes) used to create an image. Dry toner has a raised, glossy appearance on paper and can be scraped off with a scalpel. Dry toners can be either single-component or dual-component.

Dual-component toner - Toner consisting of a separate carrier material (glass or plastic beads of ca. 200 μm diameter electrostatically rechargeable) that is added before toner application to the drum and recovered afterwards, therefore, in most cases, it cannot be detected on the final copy.

Liquid toner **-** Carbon black particles or dyes suspended in a liquid carrier used to create an image. Liquid toner appears to dye the individual paper fibres.

Single-component toner - Toner that contains a magnetic carrier material (magnetite and ferrite are common) that may be detected on the final copy. Single-component comes in a magnetic and a non-magnetic form. The non-magnetic form has, however, limited applications.

Toner - Material, capable of accepting an electrostatic charge which is used in electrophotographic copying/printing processes, to create an image.

5. CROSS REFERENCES

- Ink Analysis by TLC
- HPLC

6. PRESERVATION AND HANDLING OF ITEMS

Toner examination should be performed before chemically treating the document for fingerprints as this treatment may influence the chemical composition of the toner.

Documents should be stored in paper (not plastic) file folders, which are correctly labelled. Plastic folders stick to the copy and transfer chemical substances, which can affect future analysis of the photocopier toner.

It is important to keep the documents separate from each other for two reasons:

- If they are stored in close contact for long periods of time (especially in hot and humid conditions), toner may transfer to adjacent pages thus destroying valuable evidence (e.g. photocopier trash marks).
- Sometimes numerous copies of the same document originate from different sources. If they have not been labelled appropriately prior to receipt, it is difficult to associate them to information supplied on the analysis request form. Under these circumstances, storage in separate folders with identifying details marked on the front of each folder is advised.

7. EQUIPMENT/INSTRUMENTATION/OPERATING CONDITIONS

The choice of the method is not always dependent on what one hopes to achieve, but is frequently decided by the ease of application or by the availability of particular analytical instrumentation. In general the following instrumentation can be used (list not exhaustive):

- Optical microscope, low and high power.
- Device for the detection of magnetic material.

- Fourier Transform Infrared spectrometer / Attenuated Total Reflection (FTIR/ATR), possibly coupled with a microscope.
- Scanning electron microscope (SEM).
- X-ray microprobe analysis (SEM-EDX).
- X-ray fluorescence analysis
- Laser Ablation Inductively Coupled Plasma Mass Spectroscopy (LA ICP/MS)
- Pyrolysis Gas Chromatography coupled with a Mass Spectrometric Detector (Py-GC/MS)
- High Performance Liquid Chromatography (HPLC)
- Raman spectroscopy

8. REAGENTS AND MATERIALS

- Scalpel, Micro tweezers
- Micro glass vial
- Thermostat
- Aluminium or stainless steel disks
- KBr (powder or pellet) for the Fourier Transform Infrared Analysis (if there is no ATR-unit).
- Acetone, Chloroform or similar.

9. HEALTH AND SAFETY

Special care should be taken when working with an X-ray source.

This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determines the applicability of regulatory limitations prior to use.

10. PREPARATION AND CALIBRATION OF EQUIPMENT AND REAGENTS

Prior to using any analytical method, the correct procedure to calibrate the apparatus should be taken, according to the quality management system in use. In general a calibrated standard should be measured prior to any case sample.

11. PROCEDURE

11.1. Optical microscopy

Liquid toners can be distinguished from dry toners by observation under low power magnification (circa 20x) using a binocular stereo microscope. If discrete particles of toner can be seen, it is a dry toner. Dry toners have a raised, often glossy appearance, and can be scraped off the page with a scalpel blade. In some instance the morphological aspect of the dry toner can be easily distinguished observing the document with a specular or a transmitted illumination. Liquid toners appear to have dyed individual paper fibres and appear as an even, thin coating through which paper fibres can be seen quite clearly. Liquid toner copies can sometimes be confused with documents produced by other forms of printing (for example an ink jet printer or an inked stamp).

Microscopic examination, at a magnification of 100x, can also discriminate the methods of fusion of the toner. While this is a highly discriminatory technique, it is also difficult to apply, and extreme discretion should be exercised in its use. The differences between the fusion methods are subtle and can be difficult to appreciate unless the observer has considerable experience in toner examination. One should keep in mind that the same machine can produce different toner appearances when in different maintenance conditions.

Method of toner Fusion	**Observations (100X)**
Radiant heat Dry toner	Resembles liquid tar and has a glossy bubbly appearance
Heat and pressure	The dry toner is melted and then flattened by pressure. Individual particles are discernible and have an overall compacted appearance
Cold pressure	Toner is dry and is not melted by heat. Pressure is created by a roller and under magnification toner appears as if it could be readily removed from the paper by scraping
Hot soft roller	This is a combination of heat and a soft roller that gives the dry toner a textured appearance similar to the first application of paint to a wall. Relatively few machines use this method
Hot hard roller	This fusion process melts the dry toner and the hard roller then presses the toner into the paper so that the paper fibres are highly visible. Discrete toner particles are not visible but have been melted and pressed into the paper
Hard/soft roller	The toner is fused onto the copy as it passes between these rollers. If the hard roller is on top, there will be tracks evident in the toner surface and paper fibres will be visible. If the soft roller is on top, the toner will have a textured appearance. Observation of the edge of the toner particles helps to decide the order of the rollers

11.2. Detection of magnetic material (differentiation of single or dual-component toner)

Toner powders, which contain magnetic material incorporated into the toner particles (single-component systems) when fixed onto the paper, exhibit magnetic properties similar to other forms of magnetic printing. These toner images can be magnetised by gentle stroking with a permanent magnet in one direction, and their magnetism detected and imaged with commercial magnetic detection systems.

One technique consists of scraping a little bit of toner, placing it on a glass slide, and stroking the bottom of the glass slides with a magnet. Under the microscope one can visualise the movement of the magnetised particles. See also 11.5.2.

Another technique is to use a magnetic camera to visualise also magnetic ink or magnetic straps.

11.3. Fourier Transform Infrared spectroscopy (FTIR)

Fourier Transform Infrared spectroscopy is a suitable method for the differentiation of the polymer and organic resins present in toners. Many different techniques can be undertaken for the analysis of toners by infrared spectrometry (IR).

The analysis of toners may be successfully performed by:

- Diffuse Reflectance (DR)
- Attenuated Total Reflectance (ATR) with an Internal Reflection Element (Germanium crystal for example)
- Reflection-Absorption (R-A) techniques with a variety of reflecting media including mirrored slides, low sensitivity glass, metal disks and aluminium foil
- Transmittance

Selection of the analysis technique can be made based on equipment availability, ease of sample preparation, speed of analysis, and the amount of damage that may be done to the original document.

<u>Sampling the toner</u>

The technique for analysis of toners by Diffuse Reflectance (DR) has been described in several papers. To prepare samples for analysis by DR it is necessary to remove a portion of the toner by slicing off the top layer of paper fibres from a small area of the document to be analysed. Approximately half of a single letter is required for sufficient sampling. This sample is then placed in a limited volume insert in a sample vial and extracted with 10 he technique for analysis of toners by Diffuse Reflectance (DR) has been described in several papers. To pre3 mm in diameter and 2 mm deep.

The cup is then placed in an oven at 100°C for 15 minutes to ensure complete removal of the solvent. The infrared spectrum is recorded using a diffuse reflectance accessory (the Collector) fitted to a FTIR spectrometer. (Recommended parameters: 4 cm^{-1} resolution from 4000 to 650 cm^{-1}. Each spectrum is scanned 200 times).

Attenuated Total Reflectance (ATR) does not need a specific sampling technique. The document can be directly analysed under the microscope. (Recommended parameters: 4 cm^{-1} resolution from 4000 to 650 cm^{-1}. Each spectrum is scanned 200 times).

For the Reflection-Absorption (R-A) analysis various techniques are available to lift the toner from the paper support. Successful lifting can be achieved using Aluminium or Stainless Steel discs that are heated on a thermostat at 170 - 190 °C and then placed on the front of the document for a brief moment. Once the toner is lifted onto the reflective medium, the sample is analysed under the FTIR microscope by R-A. (Recommended parameters: 4 cm^{-1} resolution from 4000 to 650 cm^{-1}. Each spectrum is scanned 200 times).

To perform an infrared analysis by transmittance the toner can be transferred from the metal disk onto a KBr pellet. Then the pellet can be analysed in transmission mode using common FTIR. (Recommended parameters: 4 cm^{-1} resolution from 4000 to 650 cm^{-1}. Each spectrum is scanned 200 times).

11.4. Scanning electron microscopy (SEM)

Scanning electron microscopy can be used to obtain detailed information on the surface morphology of toner deposits, which can be used as a means of differentiating toners.

A very small sample (1 mm diameter) of toner bearing paper can be removed from a document using a scalpel or an appropriate cutting instrument. Samples are then fixed on a SEM holder with a double-sided adhesive tape and then coated with carbon, gold, platinum, palladium or silver; the choice of the coating depends on the type of analysis to be made. Three or four micro photographs of each sample are recorded using a magnification of 500x which is found to be the most useful single magnification for observing surface morphology, although other instrumental conditions may be used to record specific surface detail as appropriate. Also, samples can be examined without a conductive coating in an instrument capable of "low vacuum" operation.

The basic method of toner fusion is (liquid toner, dry toner with heat fusing, dry toner with cold pressure fusing, and dry toner with combined heat and pressure fusing) on plain paper may be determined by SEM. However extreme caution should be used as erroneous identifications can be made based on different looking toner deposits as seen by SEM because they may be caused merely by varying settings or conditions of machines operating on the same principle.

11.5. X-ray microprobe analysis (SEM-EDX)

X-ray microprobe analysis gives information on the inorganic content of the toner. Samples are prepared and presented to the scanning electron microscope in the same way as for surface morphology examination. X-ray spectra are a useful means of differentiating toners whose appearance may otherwise be similar; and is therefore a powerful tool for the differentiation of toners.

This method can be used to confirm the detection of magnetic material (section 11.1) and allows distinguishing single component toners from dual component toners on the basis of a peak in the x-ray spectrum of single component toners originating from the magnetic carrier (iron filings, magnetite, or ferrite, and sometimes, but seldom chromium).

It must be stressed that a paper blank must always be examined. Some papers have high inorganic content from the fillers used and often the inorganic content of the paper will be reflected in a spectrum thought to be from the toner. This is particularly true in toners with a high organic content and a low inorganic content (primarily toners used in photocopiers using heat without pressure as a fusion method) where a contribution from the paper can overwhelm the modest contribution from the toner.

Due to the in-homogeneity of the paper and toner in combination with the small area of analysis, multiple sampling and analysis is recommended.

11.6. X-ray Fluorescence

The XRF method is widely used to measure the elemental composition of materials. Since this method is fast and non-destructive to the sample, so it is the method of choice for toner analysis.

11.7. Laser Ablation Inductively Couples Plasma Mass Spectroscopy (LA ICP/MS)

In Laser Ablation Inductively Coupled Plasma Mass Spectrometry the sample is directly analyzed by ablating with a pulsed laser beam. The created aerosols are transported into the core of inductively coupled argon plasma (ICP), which generates temperature of approximately 8000°C. The plasma in ICP-MS is used to generate ions that are then introduced to the mass analyzer. These ions are then separated and collected according to their mass to charge ratios. The constituents of an unknown sample can then be identified and measured. ICP-MS offers extremely high sensitivity to a wide range of elements. (cf. EAG website)

11.8. Pyrolysis Gas Chromatography coupled with a Mass Spectrometric Detector (Py-GC/MS)

Pyrolysis GC/MS is used to analyse the organic content of the toner, particularly the binder. During pyrolysis, which is usually performed at about 700°C, large molecules are broken up into smaller ones that are then separated by gas chromatography and detected by mass spectroscopy. Pyrolysis GC/MS is a highly discriminatory method of analysis with a larger discriminatory power than the above mentioned techniques. It is however quite time consuming and has a limited reproducibility. Multiple sampling and analysis is therefore recommended.

Ageing processes must be taken into account, when older documents or documents stored at stressing conditions (heat and/or light) are analysed.

11.9. High Performance Liquid Chromatography (HPLC)

Polymers and especially Charge Control Agents (CCAs) can be analysed by HPLC. Details are described in EDEWG-Method “HPLC”.

11.10. Raman spectroscopy

Raman spectroscopy is complementary technique for FTIR and sensitive to the toner pigments, dyes and polymers. No special requirements for sample preparations in Raman spectroscopy. (Recommended parameters: 4 cm^{-1} resolution from 2000 to 150 cm^{-1}. Each spectrum is scanned minimum five times).

12. RECORDING AND INTERPRETATION OF RESULTS

The differences, using a microscope, between the fusion methods are subtle and can be difficult to appreciate unless the observer has considerable experience in toner examination.

At least duplicate or triplicate measurements should be taken in order to confirm the reproducibility of the analytical techniques.

A paper blank must be always analysed, especially for the X-ray examination.

In the presence of microscopic and/or analytical differences, the analysis of toner allows to conclusively distinguish toner morphology/composition. Depending on the differences observed a printing system (photocopier, laser-printers or fax) can be eliminated as a possible source of a document. For instance, a printing system using a single-component toner does not tolerate the use of a dual-component toner.

Although a document may be identified to the type of machine that produced it, in the absence of a suspect machine and non-machine related trash marks (i.e. staple marks, inserted writings etc.), it is difficult to determine if a questioned document was produced by a photocopier or by a laser printer.

In the absence of any microscopic and/or analytical differences a printing system cannot be excluded neither identified as a possible source of a document.

13. QUALITY ASSURANCE AND COMPETENCY

A competent practitioner should be able to properly assess the possibilities and impossibilities of using the techniques for the examination of toner. They must at all times be fully aware of the limitations of the methods as stated in this procedure and must weigh their conclusions on the basis of these limitations. They must also be aware of other examination methods that may overcome some of these limitations and therefore result in a more reliable conclusion.

The competencies relevant to the examination of toner are summarised in the document: "Skills and Knowledge Base for European Forensic Document Examiners".

14. BIBLIOGRAPHY

- Totty, R., “Analysis and Differentiation of Photocopy Toners”, Forensic Science Review, Vol. 2, N° 1, 1990, pp.1-23.
- Frost, T.B. and K. Dwyer, “Office Paper Decopier“, Journal of Forensic Sciences, Vol. 46, N° 3, 2001, pp. 631-636.
- Farrell C. Shiver, “Photocopier Identification: Discussion of a Problem Associated with Multi-Generation Photocopies”, 52nd Annual Meeting of the American Society of Questioned Document Examiners, Long Beach, CA, 20-24 August 1994.
- Rena A. Merrill, BS, Edward G. Bartick, Ph.D., and Williams D. Mazzella, BS, “Studies of Techniques for Analysing Photocopy Toners by IR“, Journal of Forensic Sciences, Vol. 41, N° 2, 1996, pp. 264-271.
- Jan de Koeijer, “Identifying Black Toners using FTIR and Pyr-GC-MS“, 2nd meeting of the European Academy of Forensic Sciences, Krakow, September 2000.
- Gilmour, C. L., “A comparison of Laser Printed and Photocopied Documents can they be Distinguished? “, Journal of the Canadian Society of Forensic Sciences, Vol. 27, N° 4, 1994, pp. 245-259.
- Brandi J., James B. and Gutowski S. J., “Differentiation and Classification of Photocopier Toners – A comparison between Diffuse Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS), Energy Dispersive X-ray Microanalysis combined with a Scanning Electron Microscope (SEM- EDX), and Pyrolysis Gas Chromatography (PyGC“), International Journal of Forensic Document Examiners, Vol. 3, No. 4, 1997, pp. 324-343.
- Galliford, Chemical Toner -Seminar 2007
- Udristioiu, E. G. BunaciuA., Aboul-Enein H. Tănase, I. Gh., “Forensic Analysis of Color Toners by Raman Spectroscopy”, Instrumentation Science & Technology, Volume 37, Number 1, 2009, pp. 23-29(7).
- Szynkowska M. I., Czerski K., Paryjczak T., Parczewski A., “Ablative analysis of black and colored toners using LA-ICP-TOF-MS for the forensic discrimination of photocopy and printer toners”, Surface and Interface Analysis, 2010, 42, pp. 429-437.
- Chalmers J.M., Edwards H.G.M., Hargreaves M. D., “Infrared and Raman Spectroscopy in Forensic Science”, John Wiley & Sons, 2012, 646, ISBN: 978-0-470-74906-7.

APPENDIX 7 – OVERVIEW PROCEDURE FOR EXAMINATION OF INKJET PRINTED DOCUMENTS

1. INTRODUCTION

This method is to be used when documents produced by devices with inkjet printing mechanisms are to be examined or compared with similar documents to establish their source. The examiner may or may not have access to a suspect machine.

The techniques used are mainly microscopy and lighting techniques such as oblique light and infra-red luminescence. Additionally, ESDA or analytical techniques such as TLC, HPTLC, HPLC, CE or Raman-Spectroscopy may be employed.

2. SCOPE

This procedure will cover the examination and comparison of all kind of inkjet printed documents produced by output devices such as office inkjet printers, multifunction machines and facsimile machines (if they are the receiving fax). It does not include professional digital presses.

This procedure will be appropriate when it is desired to compare a questioned document or documents produced by inkjet printing

- with each other to determine if they were produced from the same printing source;
- with the output from a specific machine to determine if it is the source of the questioned document;
- with a collection of samples of known origin and / or database information to determine specifications about the class of machine that produced them.

3. PRINCIPLES

To undertake this type of examination it is necessary to understand the way that the various printing mechanisms function. Inkjet printing is described by Doherty [1] and Shufflebottom and Day [2]; extracts from the latter paper are included here in appendix I.

The basic method of comparison is to inspect the questioned and specimen printing for class characteristics and machine specific characteristics and record the similarities and differences between them. Because of the variable nature of the inkjet print appearance it is unusual to be able to link documents together with certainty within the exception of the dithering analysis. However, many inkjet printers will show class differences to each other, which can be used to discriminate between two documents from different printers. Care has to be taken in doing this as two documents from the same printer can appear different because different settings or paper has been used in their generation. Reasons for any observed differences must be sought.

Many of the characteristics being examined are small and difficult to see. A good microscope magnifying at least up to 40 times and good lighting conditions are therefore essential.

The following methods apply equally to multi-colour inkjet printers as to single colour as the print mechanisms are the same.

4. GLOSSARY

Bi-directional printing - Print head print from both sides - left to right and from right to left.

Continuous inkjet - Inkjet subclass in which the jet of droplets is continuous, droplets that should not reach the paper are deflected.

Dithering - Dithering is a technique to simulate the display of colours that are not in the current colour palette of a particular image. It accomplishes this by arranging adjacent pixels of different colours into a pattern, which simulates colours that are not available to the computer. In the case of inkjet printers, colours are usually approximated by dots in cyan, magenta, yellow. However sometimes photo printers also apply colours like light cyan, light magenta, grey, red and green.

Drop-on-demand - Inkjet subclass in which droplets are only generated when needed.

Edge raggedness - The sharpness of the optical transition at the edge of a printed area. Edge raggedness is determined by the ink/paper interaction (feathering), drop placement and satellites. See e.g. IS&T’s NIP18: 2002 International Conference on Digital Printing Technologies, 782-786 (2002).

Inkjet - Printing method utilising a jet of ink droplets from a nozzle directed towards a substrate.

Printer driver - Software in between the application and printing hardware, generally determines (together with the hardware) the quality and speed of the output.

Print settings - User selected options for printing quality, paper quality and speed.

Print resolution - The print resolution depends on the combination of the raster spacing of the pixels (also called the addressability) and the spot size. It is usually determined by measuring the number of dots per unit distance. The smaller the raster spacing the higher the amount of ink dots (smallest droplets) and the more precise the ink dot placement.

Solid inkjet - An inkjet printer which uses a solid (wax-based) ink which is melted in the print head and solidifies on the paper surface.

Spatter/satellites - Tiny ink droplets usually trail behind the main (intended) droplet. These droplets hit the paper later than the main droplet and therefore travel further in the direction of the print head. However, next to these slow satellites other non intended spray effects may occur as e. g. fast satellites, break-ups or mists of droplets.

Spur marks - Spur gears are used alongside rubber rollers to transport the paper from one end to another during printing. Usually made with metal, the sharp edges of the spur gears may leave tiny holes on the paper which are referred to as spur marks.

Wicking - Inks travelling along the paper fibres on strong absorbing papers due to capillary action. This effect is usually stronger for dyed based inks than for pigmented inks.

5. CROSS REFERENCES

- Recognition of Printing Techniques
- Ink Analysis by TLC
- Application of Luminescence to the Examination of Documents
- NIR Absorption and Reflection Examination of Documents

6. PRESERVATION AND HANDLING OF ITEMS

It is important to note that if an inkjet printer is not used for long periods of time the print head may become blocked. A cleaning cycle needed to unblock the nozzles may not bring the print head back to the state as it was in when received at the laboratory. To avoid this, collect print samples from seized inkjet printers as soon as possible after receiving at the laboratory.

Generally physical examination of printed documents will be non-destructive and therefore leave the documents relatively unmarked. Care should be taken not to handle the documents too much as this might destroy any evidence that can be gained from paper-handling marks.

Normally a visual and microscopic examination of the documents is carried out first followed by an indented impressions examination, including electrostatic examination of the surface for the presence of paper-handling marks. Any ink comparisons requiring extraction of the ink will be carried out after the non-destructive examinations. If a DNA examination is required then advice on the order of examination must be sought from a DNA specialist. Fingerprint examination should be carried out after all Document Examination techniques.

7. EQUIPMENT/INSTRUMENTATION/OPERATING CONDITIONS

To undertake this examination you may require:

- Stereomicroscope, x40
- Computer, capable of operating modern printing equipment together with the relevant cables.

- UV and infra-red lighting techniques, to detect absorbance and luminescence
- Oblique light source
- Electrostatic detection equipment, such as ESDA
- Reflected-light microscope, x500, (bright and dark field) software for calibrated area measurements
- Chromatographic equipment such as TLC, HPTLC, HPLC or CE
- Raman-Spectroscope

It may also be desirable to have access to other analytical techniques such as Microspectrophotometry, FTIR, X-Ray Fluorescence and Laser Ablation Inductive Coupled Plasma Mass Spectrometry (LA-ICP/MS) for analysis of the ink. Also, specific image analysis software and equipment (e.g. ImageXpert or QEA) may be used to quantify and compare image details.

8. REAGENTS AND MATERIALS

Recordable CDs should be available to download printer drivers, as necessary. Otherwise there are no specific reagents or materials required.

9. HEALTH AND SAFETY

There are no particular health and safety concerns associated with this procedure except where ESDA, lighting or analytical techniques are required. These are dealt with in the respective documents.

When operating electrical equipment from an unknown source it should be tested for electrical safety.

10. PREPARATION AND CALIBRATION OF EQUIPMENT AND REAGENTS

To undertake a comparison of samples from a machine with a questioned document it may be necessary to operate the machine. The Examiner should ensure that a suitable computer is available, together with all the relevant cables and software before attempting to make a comparison.

11. PROCEDURE

First it must be established that both the questioned and the specimen samples, if submitted, are indeed inkjet printing. Some trade names can be deceptive and the word "jet" is not always applied to inkjet printing. This is done by inspecting the documents under low power microscopy and checking for the following features:

- Liquid ink absorbed onto paper fibres
- No raised image surface (an exception to this is the solid inkjet)
- Spatter (or satellite droplets), not visible with all inkjet printers
- In colour printing, discrete dots, often slightly irregular in shape.
- Usually no regular raster patterns can be distinguished

If available, inspect the printing mechanism of the machine.

If both the specimens and the questioned document are from inkjet printers then proceed to further steps.

Because inkjet printers are controlled by the signal from a computer the appearance of the printed documents from one machine can vary greatly, depending on the operating system, the print settings and the printer drivers used. To establish that two or more documents are produced from the same printer the following conditions need to be met:

- There are no significant differences between the printing on the documents that cannot be explained by the use of different settings or different types of paper.
- There are sufficient individual features (specific to a particular machine or electronic source) to eliminate the coincidental match of another printer.

With the exception of the dot modulation (e.g. drop volume) and dithering analysis it is difficult to satisfy these conditions with certainty and therefore the comparison of inkjet documents often results in a qualified opinion.

11.1 Sampling

Where an inkjet printer is suspected of producing a particular questioned document and the machine has been supplied, suitable samples for comparison should be obtained. Ideal would be a combination where printer and associated computer or hard disk image are provided for forensic examination.

The following should be noted when obtaining samples from the printer:

- Printer manufacturer, model and serial number, ink cartridges, paper quality (if computer was provided: software, printer driver, standard printer driver setting / if available digital source)
- The settings for the printer driver which can alter the way the sample is printed. For example, if the dithering mode is ‘ON’ a printed image may differ from the same image when it is printed with the dithering mode ‘OFF’.
- The formatting of the document since this may alter the way it is printed. For example a printer may print in only one direction if there is a carriage return at the end of every line, whereas it may print in two directions (bi-directional) when the line has no carriage return at the end and is set on word wrap.

- The resolution and print mode of the printer can be varied, which can change the output. These adjustments are often connected and influenced by the setting for paper quality.
- The quality of the paper affects the edge raggedness of the dots and on strong absorbing papers wicking may occur.
- A cleaning cycle or realignment can ruin any specific features of the printer such as blocked nozzles or misalignment.
- The print head adjustment can cause a misalignment of the print colours. However, the dot pattern per colour is unaffected and reproducible.
- Some cartridges may house the print head as well, which means replacing the cartridge will replace the print head.
- Care must be exercised when handling ink cartridges as features like blocked nozzles may be changed by a simple in-and-out movement.

Taking into consideration the factors listed above, printer samples should be obtained by:

- Formatting the document as close to the questioned document as possible, including images, resolution, spacing, font and margins. If the questioned document is available on the computer use it to generate the print samples.
- Using the correct driver (and if known, same operating system and software) for the printer; if the driver is not supplied with the printer, it can usually be found on the Windows installation disks or downloaded from the Internet (usually from the manufacturer's website).
- Taking sufficient samples to ensure that the most suitable material for comparison is obtained. To do this it may be necessary to take samples using a variety or combinations of the settings of the printer driver. Be aware that non-logic printer driver settings will be corrected by the software. Therefore, it is recommended to check the settings after the print again.
- Using similar paper to that on which the questioned document was produced. Paper already in the machine should only be used for generating print samples after some has been set apart for comparison with the questioned documents (see paper comparisons). Additionally coated inkjet paper should be applied since it has shown to be most suitable for the determination of the dot pattern and satellite drops.
- If available, examine documents printed in the same period as the questioned document on the printer in question.

11.2. Examination of Class Features

The following comparisons should be made in the first instance to determine whether the specimens and questioned documents have the same class features.

11.2.1. Paper handling marks

Low angle lighting, transmission light and if necessary electrostatic imaging can reveal physical marks on the paper caused by spur gears, rollers and the pick-up mechanism of the machine. Care should be taken that there is not more than one pathway for the paper through the machine. Occasionally the paper handling device will have a fault characteristic of an individual printer, but usually all printers of the same model will have similar marks.

11.2.2. Ink

Test the reaction of the ink under different lighting conditions (visible, UV, IR absorbance, IR luminescence). The appearance of the ink may differ if it is viewed against a different background, so comparisons can only be relied upon if they are on the same paper. Ink comparison using various chemical techniques (e.g. TLC, HPLC, Raman spectroscopy, LA-ICP/MS) can be carried out later if necessary and will not be dependent on the background paper. When examining multi-colour printing, different proportions of ink may cause a different reaction. Again, chemical techniques may help this comparison, see the EDEWG methods on TLC and HPLC.

The classification in regards to the presence of pigmented or dye based inks can be helpful to eliminate printer models (use of inkjet database recommended).

11.2.3. Black Image

Some machines print black as a separate colour while others (old models) print black by overlapping cyan, magenta and yellow or again others use coloured inks to underline black text print. The number of colours used is a characteristic of the machine or the type of image and can therefore be a good diagnostic tool. The file format (text or image) in combination with the software may also determine if text is printed in pure black or by a combination of colours. This can be seen using a microscope.

11.2.4. Dot size and shape

Microscopic examination. The dot size is dependent on the print head, the ink, the print settings and the paper (difference in absorbency) that are used, so differences should be treated with caution. However, the shape of the dots and the dot sizes (constant or variable / volumes) that are present may be used to classify a printer manufacturer or even a specific printer model. As a rule, it can be assumed that if constant ink dot sizes are existent in light and dark printed areas, constant ink volumes (especially for yellow ink dots) are used by the printer in the particular print setting.

It may be possible to exclude a suspected printer as the source for a questioned document or even detect insertions in an inkjet printed document when no horizontal or vertical line shifts are present. For this examination database information (EDEWG inkjet printer database) and/or specialised image analysis equipment (microscope x500. and dedicated software to enable calibrated measurements) are essential.

11.2.5. Print dot pattern

Microscopic Examination. The dot pattern of an inkjet printed document depends on the operating system, software, electronic source, printer driver version, print settings and the print head itself. Using the same conditions this individual pattern is reproducible and therefore can be applied to either distinguish questioned documents or link them to a specific data source.

In text print mode the basic letter formation shows three different principles depending on the printer driver. The dot pattern for a character can change line-by-line, letter-by-letter or stay constant.

11.2.6. Print Direction

Microscopic examination of the spatter pattern (satellite droplets). Spatter mostly occurs on the side of the character in the direction towards which the print head is travelling at the time of printing (see appendix). However, break-up spatter and other spray effects may occur as well and need to be considered by the document examiner.

Furthermore, the print direction at the beginning of the document (first movement of the print head - left to right or right to left) is a tool to determine printer characteristics.

11.2.7. Print head size

Different printers can have different numbers and sizes of print nozzles as well as different distances between the top and bottom nozzles. If the printer has a nozzle misfiring (see section 11.3 below) then the recurring pattern of blank lines in the print may allow the dimensions of the print head to be determined. In some printers this is simply the distance between the lines; in others the print pattern is more complex. The print head size can also be determined if the print head prints in both directions if there is a misalignment problem between the two print directions. One must however take into account that sometimes printers print line-by-line and sometimes a printer prints the full length of the print head. From a continuous vertical print the size of the print head of a bi-directional printer may be derived from the change in direction of printing. With non-continuous bi-directional printing (e.g. lines of text) the minimum size of the print head may be derived from the number of lines printed simultaneously in one direction or with larger fonts from the change in satellite direction within one character. A bi-directional printer with a print head size e.g. 13,6 mm will print 4 lines of Times 8, 3 lines of Times 9, 10 or 12, 2 lines of Times 14, 16 or 18 and one line of Times 20, etc.

If the printer is available for examination it is recommended to remove the print head (after test prints were prepared) and measure the distances between the nozzles, line of nozzles and length of the nozzle lines.

11.2.8. Sequence of Colour Printing

Different machines have different print head arrangements for printing several colours. Some are side by side, others are one above the other. Usually this is not apparent from the output unless the printing is misaligned or one of the heads is failing. If the printer is present then the print sequence can often be determined by stopping the print job halfway through and inspecting the result. This is also a convenient way of determining print head size.

11.2.9. Resolution

In some instances, it is possible to calculate the raster spacing, or even the actual print resolution e.g. old style inkjet printers, in text print by measuring sequential distances between a number of ink dots. The dots may be visible as single ink droplets or can be indicated by ink spatter, overspray or wicking at the edge of a character. Be aware that this is not necessarily the true resolution but may only reveal the number of nozzles per length unit per row. Depending on the print head and manufacturer the used raster spacing and accordingly the print resolution is either 300 (150) dpi or 360 (180) dpi or a multiple of these. If the print head is available for examination the basic raster spacing / print resolution can be determined by measuring the distances of the nozzles.

11.2.10. Spur marks

Printers of different brands models may carry different horizontal arrangement of spur marks. By measuring the total number of columns of the marks, the distance between each column and the distance between the individual spur marks, the prints may be able to be differentiated from each other.

11.3 Interpretation of class features

Perceived differences between the features of the print may be due to the printer settings and not due to different printers. Particular care should be taken with inkjet printer inks, since different manufacturers can supply the ink cartridge. Consequently, the ink from two different cartridges, which can be used on the same printer may differ in composition and appearance. Also, some printers have variable dot sizes and can print with either dot size or all dot sizes together, depending on how the resolution is set. Therefore, physical class characteristics that are fixed, such as the size of the print head or position of paper handling marks etc, are usually more diagnostic than features that are controlled by software. However, the formation of the individual letters in text print – whether a line-by-line change, a letter-by-letter change, or no letter formation changes occur – are a tool to determine printer characteristics.

If the class features are the same or similar, then the documents should be examined for individual characteristics. If the class features are different then all explanations of why they are different should be considered, before stating they are from different printers. Differences may also be explained through the circumstances of the case (i.e. significant time differences between producing the questioned and specimen samples).

11.4 Examination and Assessment of Defects

The most common fault that occurs in an inkjet printer is the malfunction of one or more of the print head nozzles. This can be caused by a blockage in the nozzle itself, a burnt-out thermocouple, a poor electrical contact or breakdown of ink in the nozzle chamber. Complete failure of the nozzle will cause a blank line to appear in the printing, most obvious in single colour printing. These defects can be permanent, occurring every time the print head is used, or transient, clearing gradually during use or recurring at irregular intervals. In some printers the print head prints continuously in all areas of the paper and so the line caused by a permanent defect is a constant distance apart (the size of the print head) down the page. In other printers the print pattern is more complex, but the pattern caused by a permanent fault may occur over a period of several passes of the print head. If the machine itself is present, then it should be possible to determine the cause of the defect and the nozzle that is blocked. When a defect is present it is important to establish that it is permanent. A recurring pattern down the printed page is indicative of this. The simplest way to examine this is to photocopy the page and then mark the position of all blank lines with a horizontal line. Measurement of the distances between these lines should reveal a regular pattern, if one exists.

11.5. Basic knowledge of Inkjet Printers

11.5.1. Basic Operation

Hewlett-Packard invented the first non-impact printer in 1979 and commercially introduced the ThinkJet in 1984. Since then, the inkjet printer has become the most dominant output device used with the personal computer as it has several advantages over other printing approaches, including low printing cost, reduced printing noise, lighter weight and less expensive printing apparatus.

11.5.2. Ink Delivery

There are two systems by which ink is delivered to the paper. Early types of inkjet printers [4] used a continuous-stream method that generated a steady, constant stream of charged ink droplets which could be deflected towards or away from the printing surface by means of an electrical field. Due to their complicated structure this method is only employed now by some uni-colour inkjet manufacturers and for special applications such as printing on packaging. Second is the drop-on-demand method that only supplies ink droplets to the paper when they are instructed by the computer to form a printed image. This is the most popular method of delivery for the inkjet print head in the commercial market. This method is described in more detail below.

11.5.3. Drop-on Demand Print Mechanism

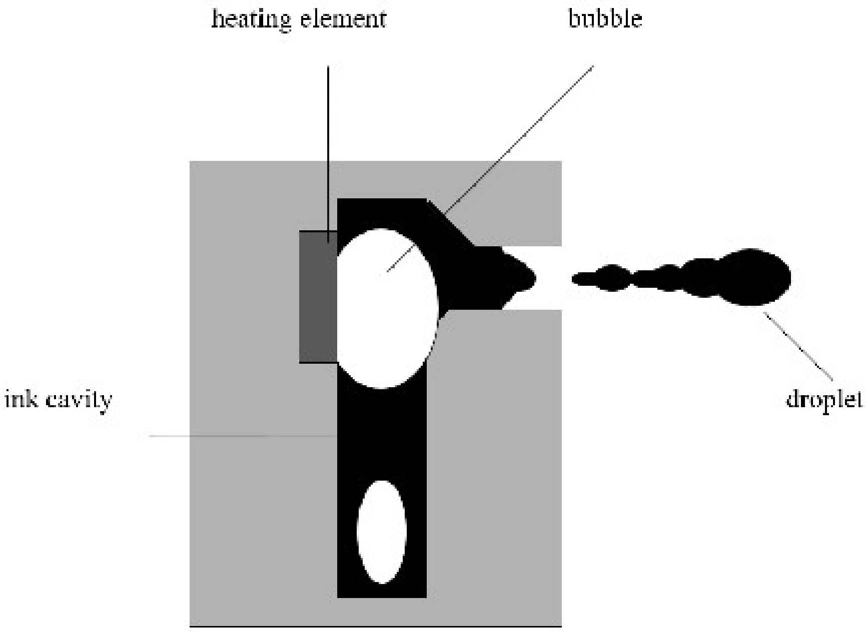
Today most inkjet printers use one of two principal drop-on demand methods to propel ink. Thermal inkjet printers use heat to generate a bubble that creates an actuating force, and piezoelectric printers use electrically driven actuators to pump ink from a chamber. The work described in this paper was performed using thermal ink-jet printers, so the mechanism for this is described in more detail below.

11.5.4. Thermal Printers

A thermal ink-jet print head consists of series of tiny holes or nozzles in a small metal plate. Behind each plate is an electrical resistor which is connected by flexible circuitry to a number of electrodes on the outside of a cartridge. These in turn connect with other electrical contacts within the printer and through which the print head is controlled. The other major component of this cartridge is the ink reservoir which contains a special ink with a high thermal expansion coefficient. A diagram of a thermal ink-jet nozzle is shown in figure 1.

Figure 1 Thermal Inkjet Nozzle

In operation a voltage pulse is passed through the resistor which causes it to heat up rapidly. The large heat flow generated is transmitted to the ink through heat conduction and



consequently produces a vapour bubble. The temperature at which the bubble forms is called the "superheat limit", which depends on the chemical composition of the ink and ambient temperature. A typical value is about 300°C at atmospheric pressure for the ink used in many commercial inkjet print heads [5]. The heating resistors can produce several thousand heat rises per second. As the bubble grows, momentum is transferred to the surrounding fluid and ink is ejected at velocities of typically 10 metres per second. After completion of ink ejection, the cavities are refilled from the ink reservoir by capillary force. Figure 2 shows a diagram of the stages of operation of a typical thermal print head.

The ejected ink droplet usually has a comet shape with a long tail [6,7]. The head and tail can separate during travel, the head becoming a separate drop and the tail forming two or more satellite drops. The result of these satellite drops severely affects the printing quality of the print head causing the appearance of ink spatter.

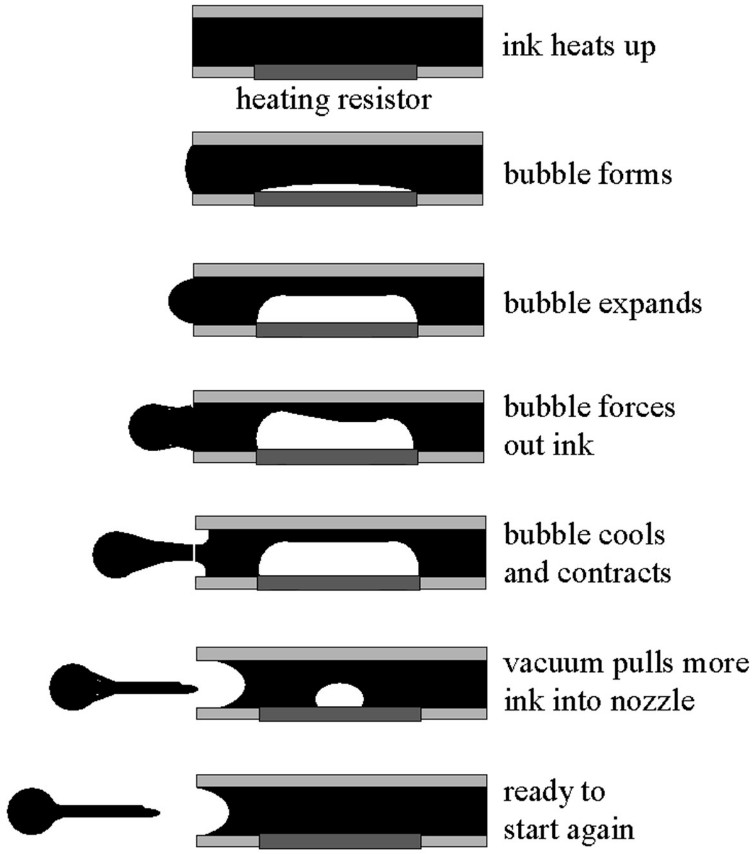


Figure 2 Stages in the Operation of an Inkjet Nozzle

11.5.5. Inks

When ink is ejected from the cartridge upon the surface of the paper it evaporates and penetrates to make a permanent mark. The inks used in the past were made up of a carrier (water or oil) and a dye combination [4]. To prevent the ink from spreading and thereby reducing the image quality, special clay coated papers were used to absorb the carriers. Manufacturers have recently developed new inks that eliminate the need for coated papers [1]. This has been done in two ways:

- By using fluid inks that dry rapidly by evaporation. Problems have arisen with this method as evaporation of some of the ink components takes place in the cartridge causing a hard plug or clogging of the nozzles.
- By using special formulated inks which are “solids" at room temperatures and become fluids when heated beyond their low melting points. These solid plastic inks are liquefied by a heater inside the printer and are then stored as a liquid inside the cartridge ready to be sprayed from the nozzle. Once the ink is ejected the ink cools quickly and solidifies on

the paper surface. The advantage of this method lies in the fact that no volatile carriers are used to dilute the inks so that evaporation in the nozzle aperture is not a problem [8].

From around 2000 inkjet inks have started changing from being dye-based to pigment-based.

11.5.6. Types of Defects and Their Causes

As with other types of printer, the principles that can be used to link a given printout to a particular printer are essentially the identification of defects and an assessment of their significance. It should be remembered that the print heads used for many inkjet printers are associated with the ink reservoir and are therefore replaced regularly. Consequently, some of the defects described below will disappear when the print head is changed.

In inkjet printers the characters are composed of dots such that the density is generally above 300 dots per linear inch and therefore the individual dots are very difficult to detect. These printers may develop faults, but it can be very difficult to detect them due to the fine dot structure. Since the print head moves horizontally, the defect can often be seen under a microscope as a horizontal white line running through the characters. The causes of some of the more common faults are listed below:

- With thermal ink-jet printers, the resistors are subjected to large pressure changes in the nozzle cavity. As the bubble collapses, it creates a microjet of fluid which impacts the surface of the resistors at high pressure. This pressure can be up to 13 atmospheres and induces cracks and craters. Once damaged it can initiate a chain of events that can cause the resistor to break open and fail [9,10]. There are also thermal stresses exerted on the print head due to the large temperature changes that occur over micro-seconds while firing. Once a resistor has failed, the nozzle will no longer print and a permanent defect will be seen in the printout.
- Sometimes at high temperatures, the dyes in the ink wall break down into insoluble fragments that stick to the resistor surface. This build up of fragments of degraded dye reduces the heat transfer to the ink and in severe cases the ink cartridge will no longer fire [8]. This effect is known as Kogation. Again, this will give rise to a permanent defect.
- At low temperatures, the thickening of the dye-carrying agent can cause the nozzles to clog [11]. This can also happen when a nozzle has been idle for some time as viscous plugs can form due to evaporation. This type of defect is likely to be cleared when the head is cleaned and is not therefore of much use to the Document Examiner.
- Occasionally, nozzles will misfire due to the continued heating of a neighbouring nozzle causing the ink to reach its superheat limit. This defect is intermittent.
- A nozzle can appear to be blocked when the connection to the printer is severed, either by an electrical fault (in which case it is likely to persist) or by dirt on the electrical contact (which may or may not persist).

Hewlett-Packard are currently using a thermal inkjet system similar to the one described above in their Deskjet range. As the print head is attached to their ink cartridges, the print head is changed every time the cartridge runs out of ink. HP print heads therefore, are not subjected to thermal stresses for a prolonged time. Some manufacturers also use Hewlett-Packard thermal print cartridges in their machines e.g. Brother while Lexmark and Canon use their own thermal inkjet delivery system for most of their more common printers. While the designs differ in the arrangement and number of the nozzles, position of the electrical contacts etc. the basic components of the cartridges remain the same.

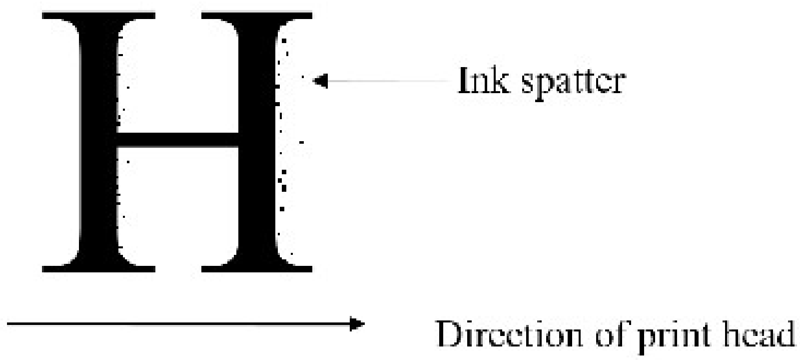
Piezoelectric systems do not heat the ink and so there are no thermal stresses exerted on the print head. This should eliminate the need for periodic print head replacement, so the print head will last the life of the printer. Epson are currently using a system similar to this in their Stylus range under the trade name MicroPiezo™. MicroPiezo™ uses tiny crystal pumps to control each ink droplet with absolute precision. The manufacturers claim the technology produces more spherical dots and less satellite droplets (or spatter) than the thermal systems. It also can achieve higher resolution (up to 1440 dots per inch compared to 1200 dpi) as the print head does not have to wait while the ink cools before it can be re-fired, thus it can operate at higher frequencies.

11.5.7. Print Direction

Some machines can print in both directions while some can only print in one direction. Further the pattern of printing is not always left to right then right to left. Sometimes the print head will travel several times in one direction then several times in the other, depending on what it has to print. From viewing the printouts underneath a microscope, the direction of print can be found by looking at the ink spatter. This predominately occurs on the side of the printed character towards the end that the print head is travelling. This can be seen in figure 3. Thus, if the bulk of the spatter is on the right of the character then the print head was travelling from left to right (it occurs on the leading edge). The reason for this can be easily understood by referring back to figures 1 & 2. The comet-like tail of the ejected drop is ejected slightly after the main drop and therefore reaches the paper slightly further along the paper than the main drop, resulting in the spatter. The amount of spatter will vary from machine to machine.

By looking at these spatter patterns one can see when the direction of the print head changes direction of print and consequently this provides a method of estimating the size of the print head nozzle array. This is a feature that cannot vary and is therefore very useful in distinguishing between printers using different cartridges or different manufacture.

Figure 3 Diagram showing ink spatter



Occasionally ink droplets from the tail can travel through the main droplet and reach the paper in advance of the main dot, creating spatter on both sides of the character. However, this is uncommon.

12. RECORDING AND INTERPRETATION OF RESULTS

If specimens from a printer have the same class characteristics as the questioned documents but do not show individual features (defects, ink dot pattern) then all that can be said is that the specimen printer could have produced the questioned document.

If the specimens and the questioned document have different class characteristics and this cannot be due to different software, paper, file type (text or image) or the time between printing one and the other then they can be said to be from different printing sources. The strength of this conclusion will depend on the specific differences found.

If the same defect is detected in the specimens and the questioned document, then it should be noted and needs to be assessed to determine the likelihood of another printer coincidentally having a similar defect. Once this assessment is made the level of support for the view the documents were or were not printed on the same printer can be estimated. It is generally easier to dissociate a printer than to associate it with the production of a document.

If the documents have the same class characteristics (including ink dot sizes, shapes etc.) and same individual drop modulation then the conclusion can be drawn that a connection (electronic source, software, printer driver, printer model) between the documents is present.

If the documents have the same class characteristics but different defects then often it cannot be established that they were produced on the same or different machines, since the defects may have occurred on the same machine at different times or on different machines. The examiner must decide on the basis of experience or from examination of known documents printed at different dates on the printer under examination how permanent these defects are and therefore how significant the observed differences are.

13. QUALITY ASSURANCE AND COMPETENCY

All results that are open to interpretation should be checked by an independent examiner.

14. BIBLIOGRAPHY

- Doherty, P., Classification of Ink Jet Printers and Inks, Journal ASQDE, Vol. 1, no. 2, December 1998, pg. 88-106.
- Day, S. P., Shufflebottom, L., Evidential Value from Ink-Jet Printers, EAFS, Krakow, Poland, 2000.
- New Zealand Police, Document Examination Printing Processes.
- Uri Levy, Gilles Biscos, “Nonimpact Electronic Printing: The reference handbook”, Interquest 1998
- Webster, E, “Print Unchained – Fifty Years of Digital Printing, 1950 – 2000 and Beyond – A Saga of Invention and Enterprise”, DRA of Vermont, Inc., 2000
- Pond, S.F., “Inkjet Technology and Product Development Strategies”, Torrey Pines Research, 2000
- Adams, J.M., Faux, D.D., Rieber, L.J., “Printing Technology, 4th Edition”, Delmar Publishers, 1996
- Kipphan, H., “Handbook of Print Media – Technologies and Production Methods”, Springer 2001
- Rolf Fauser, Cybernetic Fingerprint of Inkjet Printer Drivers, EDEWG Conference, 2006
- Rolf Fauser, Drop Modulation Technology, EDEWG conference, 2008
- Rolf Fauser, Workshop Inkjet-Printing, EDEWG conference, 2010
- http://aic.stanford.edu/sg/emg/juergens/proces03.htm
- www.imaging.org

APPENDIX 8 – OVERVIEW PROCEDURE FOR EXAMINATION OF TYPEWRITTEN DOCUMENTS AND TYPEWRITERS

1. INTRODUCTION

This method is to be used when documents produced using typewriters are to be examined or compared with similar documents to establish their source. The examiner may or may not have access to a suspect typewriter.

The possibilities to examine a photocopied typewritten document are estimated.

Also, the method is applicable for obtaining information from typewriter ribbons.

2. SCOPE

2.1. System identification

Identification of typeface and variant (including identification of the type carrier), ink or toner.

2.2. Identification of the make

Having completed the system identification, it is possible to list those makes that have been equipped with this typeface. It is nevertheless important to take into account that it is not necessarily the case that all make names are known and indicated on the corresponding compilations. It is furthermore noteworthy that golf ball heads and daisywheels may be compatible with more than one product line. Devices with an identical design may also be marketed under several company and make names.

2.3. Individual identification

In addition to determining the system and listing the makes in question, a typewriter/golf ball head/daisywheel or printer may be identified in all those cases where the typescript shows individual characteristics that make this particular device different from all the other devices of the same design.

2.4. Links between offences

If there are such individual characteristics, a comparison of the exhibits will help identify or exclude links between several documents.

2.5. Dating

Based on the details of the system, the date when a typeface/variant was introduced may prove that certain hypotheses can be ruled out.

The relative date of a typescript can be determined if characteristics of evidentiary value have been found that were seen only during a certain period of time. Under these conditions, the changes in the characteristics will help to date the questioned document if there is sufficient reference material known to be from specific periods of time.

2.6. Reinserted documents

Measuring grids adequate for the line and character spacing in question, or electronic image processing that allows for similar grids to be created, can be used to examine whether a document has been written in a single session or whether further text has been added later on.

2.7. Carbon ribbon examination / paper fibre transfer

In certain cases, comparing a carbon ribbon to a document or type carrier may prove whether the document has been created with this ribbon or whether it can be linked to the type carrier.

3. PRINCIPLES

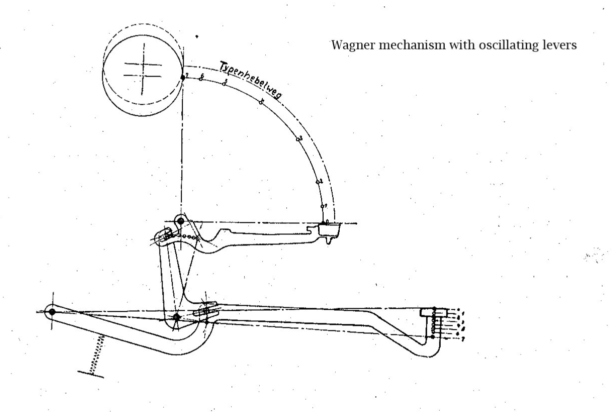
3.1. General

Printing methods can in general be divided into two main categories: the impact and non-impact methods. Typewriters fall under the full character impact methods of printing, where a character as a whole impacts the paper as opposed to matrix impact printer (the dot matrix printer) where individual pins aligned in an array strike the paper to build up a character out of dots.

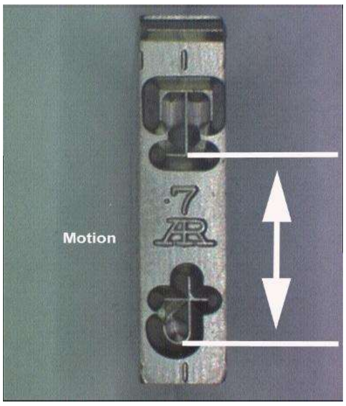
Based on the typewriting mechanisms three types of typewriters can be distinguished: the type bar typewriter, the golf ball head typewriter and the Daisywheel typewriter.

3.2. Type bar typewriter

The technical development of the type bar typewriter produced numerous different mechanisms, but in the end, the Wagner design with its oscillating levers was most successful. Type bar typewriters are marketed for purely manual operation or as electrically operated writing instruments.



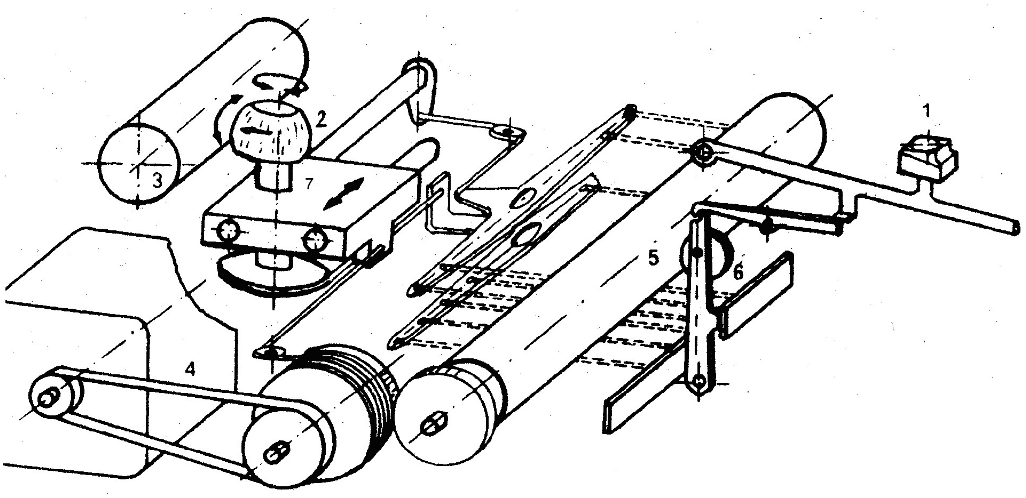
Only very few manufacturers of typewriters have also produced the types themselves (for instance, Olympia, Brother); the types are usually bought from suppliers. The leading manufacturers of steel types have been the companies Ransmayer&Rodrian and CSA.



Motion

In order to shift type bar machines from upper case to lower case and vice versa, it is necessary that either the carriage or the segment be moved. If it is possible to measure this motion during the examination, the result may help to reduce the number of possible models.

3.3. Golf ball head typewriters



1.Key
2.Golf Ball Head
3.Platen
4.Electromotor
5.Selection drive
6.Cam Carrier
7.Type Carrier Carriage

All the letters on a golf ball head typewriter are located on a rotating and tilting plastic head. During typing, the required character is moved to the right position by rotating and tilting the golf ball head. For the strike, the whole head/carrier system is moved.

Only the relatively lightweight plastic head and its carrier are moved, it is not necessary that the carriage be moved (exceptions: BROTHER, OLIVETTI). This considerably improves typing comfort. However, the biggest advantage is that various typefaces can be used by simply exchanging the golf ball head.

As with the production of steel types, golf ball heads are also manufactured by suppliers (for instance, CSA, GP).

The relatively short era of the golf ball head typewriters began when they were first introduced into the market by IBM in 1961. Although numerous manufacturers of typewriters presented similar systems once IBM's patents had expired, the golf ball head technology soon became obsolete when the daisywheel typewriter was introduced. Golf ball head typewriters are no longer produced nowadays.

3.4. Daisywheel typewriters

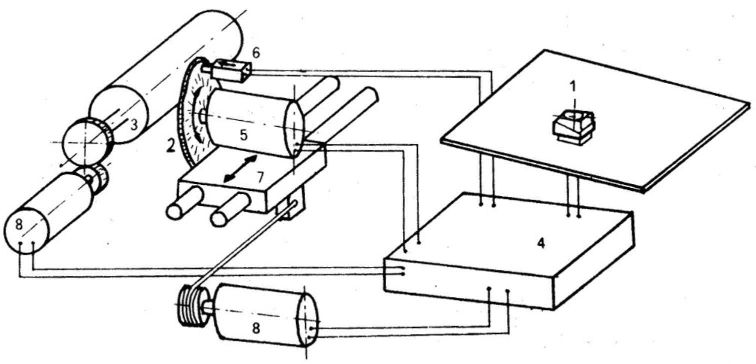
Daisywheels are made of metal/plastic or plastic, with the plastic daisywheels falling into the categories of monoplastic or duoplastic daisywheels. It is difficult to decide on the material since a compromise between the elasticity of the spoke – which must return the daisywheel to the initial position after the strike – and the hardness of the type. Therefore, a metal daisywheel with plastic types or a duoplastic daisywheel were preferred at first, but nowadays the market offers nearly exclusively monoplastic daisywheels.

The daisywheel is mounted to the rotor of a stepper motor (5), which – together with the hammer (6) and the ribbon cartridge – rests on a carriage. The daisywheel is rotated into the required position and the hammer strikes the character.

The electronic control allows connecting the daisywheel typewriter to a computer or to equip the typewriter itself with memory elements and electronic extras such as displays, spelling support etc.

It is furthermore easy to implement proportional fonts, justified composition and bold print thanks to the stepper motors.

As with the earlier typewriter designs, daisywheels are also commonly purchased from other suppliers.



1. Key
2. Daisy wheel
3. Platen
4. Microelectronics
5. Daisy wheel stepper motor
6. Hammer
7. Daisy wheel carrier carriage
8. Stepper motors

4. GLOSSARY

Typewriter and typewriting - a machine which is self contained and can, without connection to any other machine, produce documents according to the instructions typed into its own keyboard. Material produced using such a machine is said to be typewritten or called typescript.

Fixed design typeface - a typeface which is produced by a machine and that cannot be altered electronically by the machine, directly or indirectly. Thus the typeface of that machine cannot be altered except by physically removing the printhead or printing element.

Printhead - a device which causes typewriting to be produced on a document.

Printing slug - the part of an impact printhead, which contains one or more characters. Therefore this is the part of the printhead, which actually transfers a character onto a typewritten document.

Fabric ribbon - a ribbon made of fabric soaked in printing ink which the printhead hits to transfer a character onto a document. Fabric ribbons can only be used with impact printing mechanisms. They occur in a variety of colours and can have two or more colours on a single ribbon.

Carbon film ribbon - a ribbon consisting of a layer of coloured (usually black) plastic (or "carbon") stuck to a clear plastic carrier. In operation an impact printing mechanism causes the "carbon" to transfer onto the document leaving a clear hole on the ribbon in the shape of the character typed.

Multi-strike carbon film ribbon - a carbon film ribbon with several layers of plastic, which can therefore be passed several times through a machine.

Correction ribbon - a clear, sticky ribbon used in conjunction with carbon film ribbons or multi-strike ribbons to lift typed characters away from a document and thus to make corrections to a piece of typing.

Ribbon cassette - the plastic housing and associated cogs and springs used to house a ribbon so that it can be easily removed from a machine.

Raw-1 or ribbon analysis workstation - the piece of equipment with which a ribbon which retains information can be read.

Typewriter grids - clear pieces of plastic with finely ruled lines thereon, the lines being spaced in such a way that they correspond to the different spacing of typewritten characters. There are grids for all common spacing. They are used to look for misalignments in a typewritten document.

Reference material - reference material is the material with which the questioned document is to be compared. It may consist of another typewritten document (usually from a known source), samples taken by the examiner or a typewriter itself and the samples prepared from it.

5. CROSS REFERENCES

- Recognition of printing techniques
- Application of Luminescence to the Examination of Documents
- Ink analysis by TLC

6. PRESERVATION AND HANDLING OF ITEMS

Generally, this technique will be non-destructive and therefore leave the documents relatively unmarked. Care should be taken not to handle the documents too much as this might destroy any evidence that can be gained from paper-handling marks.

Normally a visual and microscopic examination of the documents is carried out first followed by an indented impressions examination, including electrostatic examination of the surface for the presence of paper-handling marks.

7. EQUIPMENT/INSTRUMENTATION/OPERATING CONDITIONS

- Stereomicroscope, x50
- Typewriter grids
- Measuring lens with scale graduations 0.1mm
- Comparative measuring microscope
- Electrostatic detection equipment
- Ribbon analysis workstation
- Typescript classification systems
- Reference material

8. REAGENTS AND MATERIALS

There are no specific reagents or materials required.

9. HEALTH AND SAFETY

There are no particular Health and Safety concerns associated with this procedure except where electrostatic detection equipment is required. These are dealt with in the respective documents.

When operating an electrical typewriter from an unknown source the equipment should be tested for electrical safety.

10. PREPARATION AND CALIBRATION OF EQUIPMENT AND REAGENTS

To undertake a comparison of samples from a machine with a questioned document it may be necessary to operate the typewriter.

11. PROCEDURE

11.1. Initial examination

The following tests and examinations must be made or considered prior to the actual typescript examination.

11.1.1. Homogeneity of the questioned material or material to be examined.

Check whether the questioned material can reasonably be regarded as homogeneous. Components of non-homogeneous typescript can be recognised on the basis of:

- letter type (form and dimensions of the characters);
- characters distance (pitch);
- the position of a part of text in relation to the regular pattern of the previous text on the document (layout);
- photocopier characteristics;
- machine-specific characteristics (damage, deviating positions or prints of characters);
- type of ink application (such as textile ribbon, carbon film ribbon, toner);
- non-uniform ink colour (if a global colour comparison provides an inadequate conclusion by visual inspection, a comparative ink examination with the aid of the infrared luminescence method and/or a thin-layer chromatographic analysis is also possible);
- non-homogeneous print (note relief on the reverse of the paper, especially in the case of possible additions);
- dating.

If the questioned typescript can reasonably be regarded as a whole, proceed with item 11.1.2.

If components can be distinguished on the basis of the above or other arguments that indicate the contrary, note what components are concerned and how these components are dealt with further (e.g. "*left out on account as evidently non-relevant*", or "*each compared individually with the available reference material*").

11.1.2. Homogeneity of the reference material

Check whether the reference material can reasonably be regarded as a whole (use the points mentioned in section 11.1.1 for this purpose).

11.1.3. Comparability in principle of the material to be examined

Consider whether the material is comparable in principle, in other words whether the typescript or parts thereof are qualitatively and quantitatively viable for a comparative investigation. A distinction must then be made between the questioned and the reference material. If the questioned or reference material is not comparable in principle, there may be various reasons for this:

- too few characters;
- photocopy quality;
- quality of a fax;
- overwritten with e.g. handwriting or stamps;
- treatment of the document with e.g. agents to develop fingerprints;

- any other causes.

Check whether parts of the typescript may well be comparable and note this on the examination sheet.

If the material remains not comparable in principle (i.e. the problem cannot be remedied by asking for additional material or the originals of documents provided in copy form), there is no point in proceeding with the investigation.

11.2. Dividing typescript into letter type classes

11.2.1. General

As there are approximately 6,000 typefaces and variants for the classic typewriting systems (type bar, golf ball head and daisywheel typewriters) it is necessary to use a classification system when building up and maintaining a collection of standards for reference, which makes it possible to quickly retrieve the typeface searched. Examples of commercially available classification systems are: the Haas Atlas and the Druïde system.

11.2.2. Examples of typescript classification

Below an example will be given of the typescript classification system of the Bundeskriminalamt. It covers the basic elements posture, style and size of the font, and character spacing, as well as the key letters a, g, f, w, r, and t.

Posture

- Upright
- Italic forward
- Italic backward

Style

- Pica-Style
- Print with uniform stroke width and serifs.
- Shadow fonts
- Print with varying stroke width and with serifs.
- Block fonts
- Print with uniform stroke width, without serifs (with the exception of "r", "i" and "l" in some block fonts).
- Monotone fonts
- All fonts including a few characters that diverge strongly from the standard basic letterform of the other characters.
- Script-style fonts
- Print that imitates handwriting.
- Calligraphic fonts

- Others fonts

Size

Classification according to DIN (German Institute for Standardisation)

- Micro up to 2.1 mm
- Elite between 2.1 mm and 2.3 mm
- Pica between 2.3 mm and 2.6 mm
- Medium between 2.6 mm and 3.2 mm
- Plakat from 3.2 mm

The size is measured from majuscules without any optical corrections or minuscules with ascenders.

In addition to these standard sizes, there are special sizes such as elite-wide, which designates a font with a height belonging to the elite size and a carriage step belonging to the pica size.

Character spacing (carriage step)

If the character spacing is constant, the value measured is directly recorded, for instance 2.54, or 2.12.

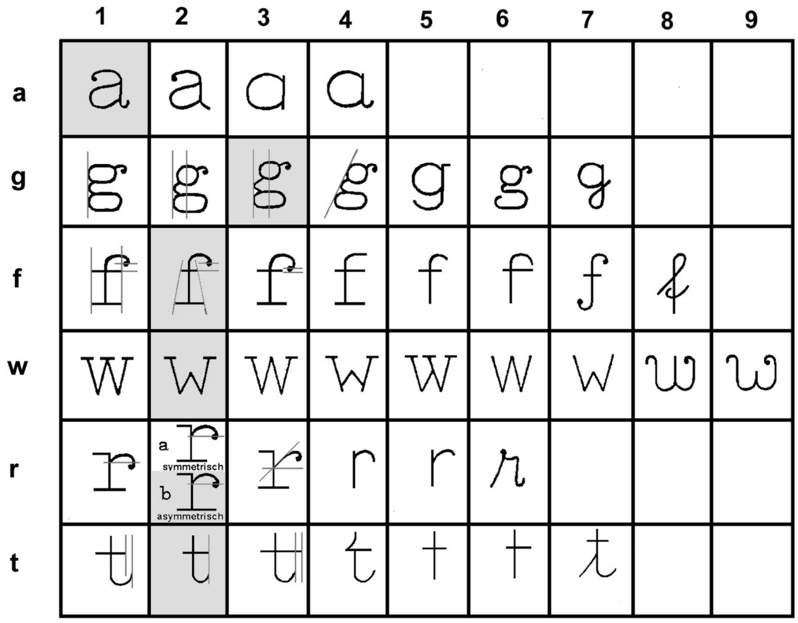
For proportionate character spacing the font is recorded as "Pp".

Key letters

Approximately 30 years ago, the BKA introduced the key letters a, g, f, w, r, and t.

The idea behind this choice was that these letters are relatively frequent in German and that there should be a sufficiently wide range of variants. These criteria have been important since the BKA does not only maintain a collection of standards, but also a collection of incriminated documents that needed to be classified along the same lines.

Basic letter forms



The key letter classification of the BKA system is applied to all typefaces.

11.3. Reference material

Once the procedure has been established as suitable, the reference material is checked to ensure that it is produced using a similar printing mechanism and is suitable for comparison with the questioned material. If it is not, no further action need be taken.

Where a machine suspected of producing the questioned document has been supplied then suitable samples can be taken direct from the machine. Before doing this the platen must be inspected using oblique light and specular reflection for any typing that has been left impressed onto it or typed directly onto it. If found, it is evidential and intelligence value should be assessed before taking samples.

Use of the ribbon originally fitted on submission should be avoided where possible, as this may affect evidence that can be obtained from the ribbon. All such ribbons, including correcting ribbons, should be removed from the machine prior to sampling, and inspection of these items carried out as described in this document (11.9).

The choice of samples is left to the QD examiner, but generally they will consist of at least three full strikes of the keyboard and a passage from the questioned document, again typed out three times.

When no machine is available the reference material may be in the form of samples taken from a machine by the examiner or a typed letter from a known or unknown source. This may limit the comparison that can be made as not all characters may be present in the reference material, and no tests may be carried out to investigate possible damage or deviations.

The typeface on the questioned document is now compared with the typeface of the reference samples. Letters are compared individually and notes should indicate where matches and differences occur. Where a difference is found and the QD examiner is satisfied that it is a design difference then no further examination is necessary.

If the typeface matches then both the horizontal (known as ‘pitch’) and vertical spacing should be measured.

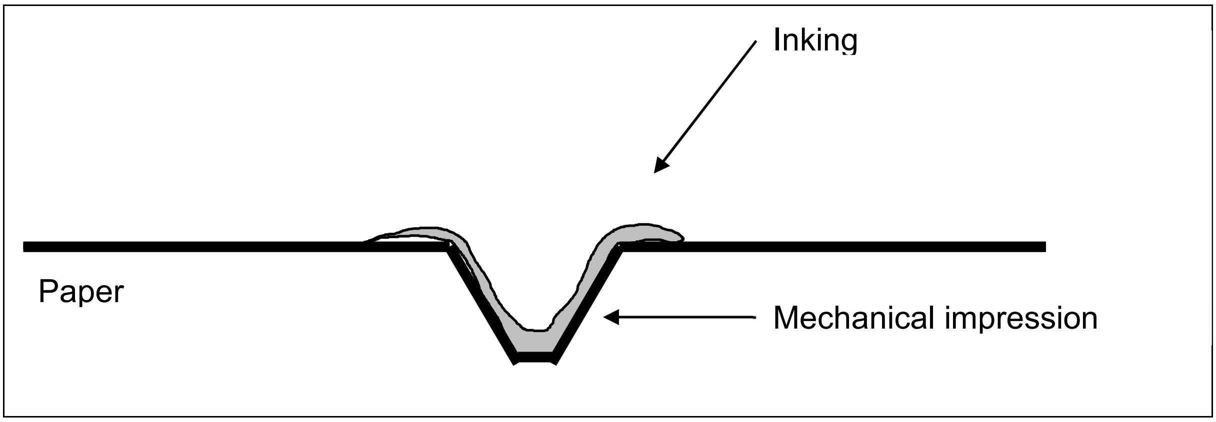
11.4. Measuring method

As a principle, characters need to be measured with the help of a stereo microscope and adequate stage micrometers.

In order to obtain results that are adequate for comparison, it is necessary to follow a standard measuring method. This method has been designed to minimise the risk of errors through adequate measuring norms.

Interfering factors such as uneven ribbon inking and impact force should not have an impact on the results.

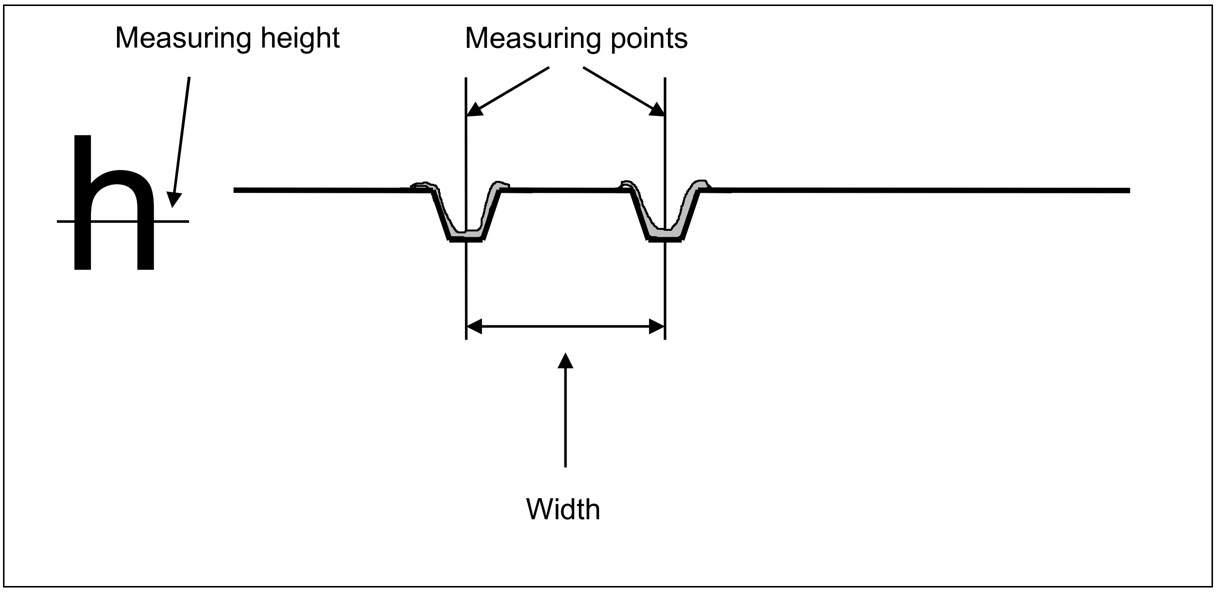
It is necessary to take into account that in original prints from impact printers the inking is always wider than the mechanical impression.



Type bar typewriters with a fabric ribbon

The width of the inking created with fabric ribbons strongly depends on the condition and age of the ribbon. A new ribbon will cause considerably wider inking than a used, old ribbon. In order to avoid that these variations have an impact on the results, measurements are always taken from the middle of one indentation to the middle of the second indentation.

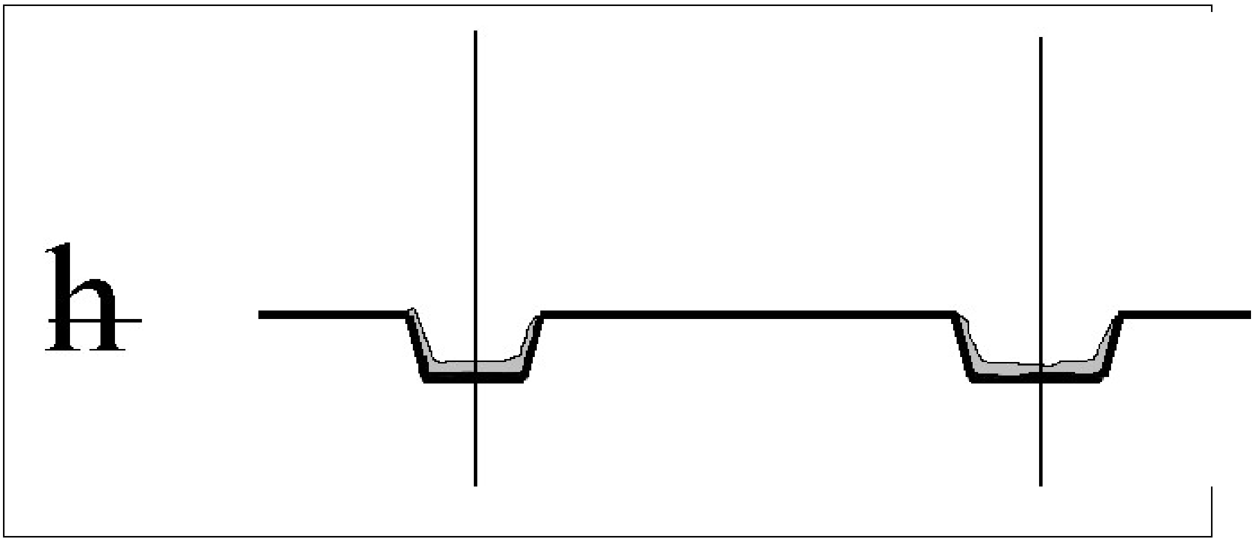
For example: Width of the letter "h" at the height of the stems. Serifs at the top or bottom are not considered while measuring the width.



Daisywheel or golf ball head typewriters with a carbon film ribbon

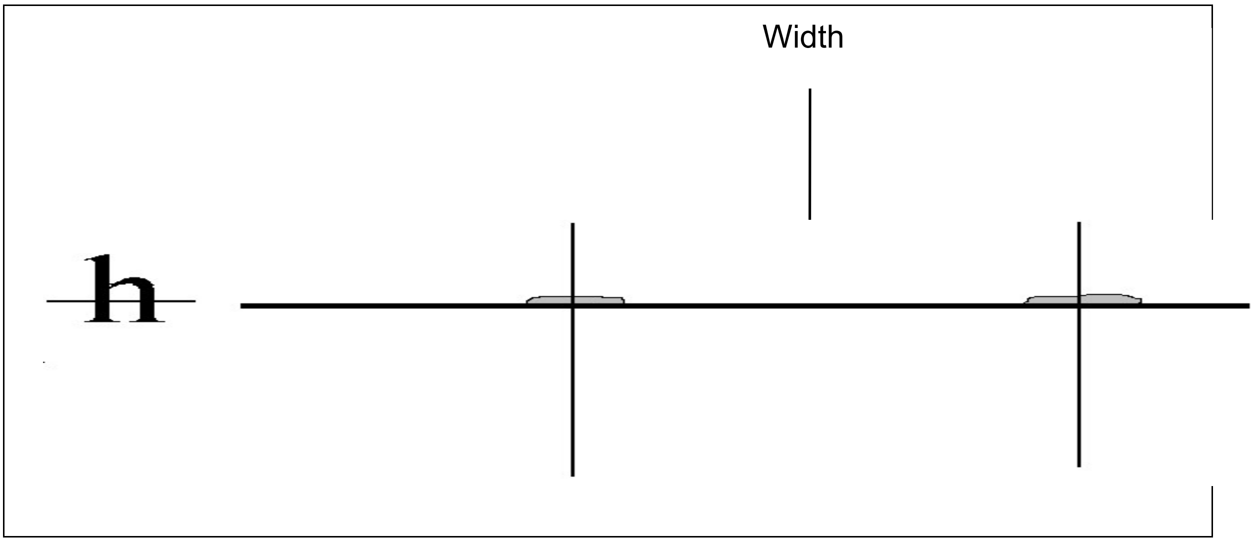
These combinations create impressions that are different from those left by type bar typewriters with a fabric ribbon. The edges of the colour deposited are more clear-cut and the indentation it not as deep.

In these cases, the measurements are also taken according to the same principle: From the middle of one indentation to the middle of the second indentation, determining the middle of each indentation by separate measuring if necessary.

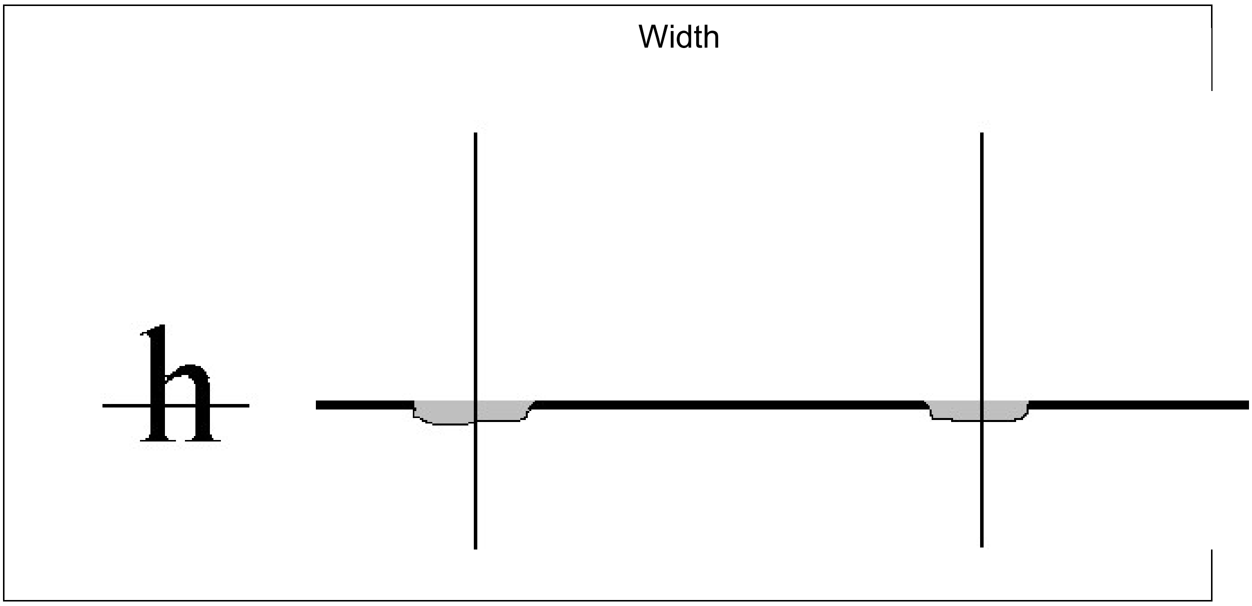


Photocopies/laser prints

Photocopies, laser prints and other "non-impact" prints do not have any mechanical impressions. Thus measurements must be taken from the middle of one line of ink to the middle of a second line of ink.



Please note that in the case of ink-jet and thermal sublimation printers the ink or dye penetrates into the paper.



In the case of original documents typed on classic typewriters, the middle of the strokes can be determined relatively precisely thanks to the three-dimensional indentations in the paper. Thus, the conditions for obtaining exact measurements are ideal.

When taking the measurements from photocopies, it is necessary to take into account that the optical system of the photocopier may have caused distortions. Thus, the measurements are not only influenced by the lack of a three-dimensional mechanical impression, but also by usually unknown parameters of the photocopier.

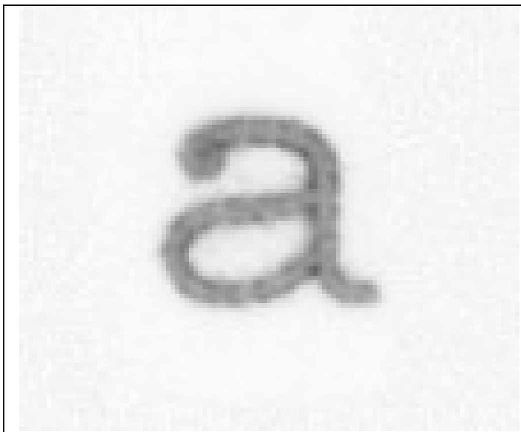
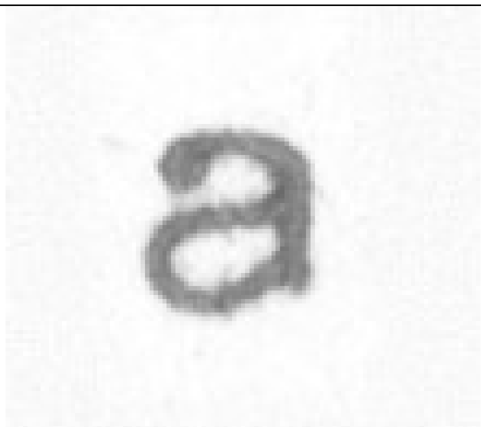
11.5. Typewriter specific characteristics

Individual characteristics are in principle defined as any divergence from the desired form and impressions of the types as determined by the manufacturer.

Individual characteristics may be typeface defects or alignment defects.

11.5.1. Typeface defects

Typeface defects are mutilations of those elements that create the characters and are caused by wear, inappropriate use, and flaws in the material. Typeface defects can only be detected by comparing the characters from the exhibit to the typescript standards obtained from undamaged typewriters or type carriers. Typeface defects can only be remedied by manipulating the device and have therefore a relatively high evidentiary value.

	
Original character	Damaged character

11.5.2. Alignment defects

Alignment defects may be:

- Vertical misalignments of characters.
- Rotated characters.
- Impact faults.
- Combinations of these three.

In principle, typeface and alignment defects may occur in all kinds of devices, but it may be observed that the frequency and nature of the individual defects strongly depends on the design of the devices. It is, for instance, very uncommon for golf ball head typewriters to show typeface damage.

Beispiel für Justierungsdefekte

Example of vertical misalignment and rotation of the characters "b" and "f".

The following section illustrates the various kinds of alignment defects taking the type bar typewriter as an example:

The cause for vertical misalignment of characters may be a defect in the case shift mechanism. If this is the case, the misalignment will occur only where the shift mechanism has been used. However, this may also be due to inappropriate handling by the author, which makes it difficult to give a definite judgement. Only if the fault shows in an absolutely identical fashion in all occurrences, is it legitimate to conclude that this is an inherent defect of the device. If the defect occurs in various fashions, it may be due to a defect of the device, for instance a less than perfect case shift mechanism, or due to inappropriate handling by the user.

Statistically distributed vertical misalignments may be caused by segment errors, i.e., the joints of the type bars within the segment may be worn, thus printing the character at a position that is too high or too low for the intended line of print.

Rotation may be due to twisted type bars. A reason for this may be that several type bars had caught together and that they were disentangled by bending them.

Uneven impacts, which lead to an uneven mechanical impression and uneven inking, are also called impact faults.

These defects may be due to a misaligned platen, misaligned case shift mechanism, segment faults, or rotated types. If all characters show the same kind of uneven impact, it can be assumed that this is due to an error in the alignment between the segment and the platen. However, if the impact faults are statistically distributed, it is not possible to further determine the reason for this.

For type bar typewriters it is under certain circumstances possible to measure the motion as well. If postcards, envelopes or similar papers were typed on or if the paper pressure roll was not fixed correctly, it may be possible to detect the second character on the type slug.

The motion measured may help to differentiate the models in question by machine size.

Some of the aforementioned individual characteristics may also occur with devices of other designs. However, as a consequence of the technology, golf ball head and daisywheel typewriters will not have any case shift or segment defects.

In very rare cases, golf ball head typewriters do have rotated characters. This effect occurs when one or several of the locking teeth of the golf ball head have been broken off.

Daisywheel typewriters may show impact faults if the hammer has been misaligned.

Generally, alignment defects:

- may be temporary in nature,
- may become stronger or weaker,
- may disappear if certain parts of the devices (golf ball head, daisywheel) are replaced,
- may be strongly influenced by the user.

Therefore, the evidentiary value of alignment defects is far lower than that of typeface defects. This needs to be taken into account to a large extent when evaluating the observations.

11.6. Recording damage

If a type sample can be made, the damage is recorded. If a type sample cannot be made and the symbol has been printed with a textile ribbon or if the document has been photocopied, the form of the damage and its position are indicated globally in the sketch of the character concerned. If a carbon film ribbon is used and the text has not been photocopied, a detailed sketch is made of the form and position of the damage. The sketches are made on the examination sheet.

11.6.1. Deviations in positioning a character

If the position of a character deviates, one or more of the following phenomena, amongst others, can be observed:

a) the character stands above or below the imaginary written line;

b) the character is tilted to the right or left;

c) the character stands too far to the left or to the right in the regular pattern;

d) all capitals stand above or below the imaginary written line. This is regarded as a single machine-specific characteristic. This characteristic is due to a **maladjusted caps-shift key**;

e) the characters on the keys located on one side of the keyboard print-out higher than the characters on the keys located on the other side of the keyboard. With this impairment, the **guide** is **maladjusted**;

f) an irregularity in the line distance due to the paper slipping when changing the line;

g) an irregularity in spacing between characters at some points within a line;

h) the characters on the left hand side of the paper do not appear beneath each other. This impairment is due to an error in the left hand line stop;

i) characters on the right hand side of the paper are typed on top of each other. This impairment may be due to a faulty right-hand line stop;

j) variations in the positioning of a character (the character "*dances*");

k) irregularity in the positioning of characters as a result of a faulty "*pitch*" following use of the tabulator key.

Deviations in positioning may often be found in a certain **combination** of characters.

The examiner checks which divergent positioning appear in the typescript to be examined. He is guided by the checklist formed from items (a) to (k) above. The deviations found are indicated on the examination sheet, if possible giving one or several causes, as indicated above.

11.6.2. Recording deviations in the positioning of a character

All deviations can be described in principle. However, use can also be made of sketches of text parts in which the divergence of a character or of a combination of characters is indicated by symbols. The table below lists some symbols used for some of the situations described above. The results are noted on the examination sheet.

Situation	**Symbol**	**Remark**
a	□ or □	if it is not clear whether the one character or the other is too high or too low in a combination of characters, a horizontal bar is placed at different heights under each of them in the character combination concerned;
b	or ⤸	a curved arrow clockwise or a curved arrow anti-clockwise
c	□ or □	these symbols are placed above or beneath the character concerned in part of a text.

11.6.3. Deviation in ink application for a character

The ink application for a character may be irregular, be partly missing or be partly printed in a different colour. A character may also be printed more heavily or less heavily than other characters.

The following causes may be the reason for the deviation in ink application:

- the **ribbon mechanism** and/or the capital letter key does not function properly. Part of the characters are not printed or are printed in a different colour;
- the ribbon is worn or the ink is irregularly applied. The ink application of the characters is then irregular;
- the character is **soiled**: additional ink (soiling) is printed with the character;
- the writing element is misaligned. The character is consequently irregularly printed;
- the stroke adjuster on the writing element is mis-set. The character is then printed more heavily or less heavily than the other characters. When examining this deviation, account must be taken of the fact that with non-electrical typewriters the strength of the character strike is also determined by the typist;
- the writing element is damaged. Damage of this kind may result in the ink of a character being irregularly distributed.

The examiner checks which characters in the typescript to be examined display signs of irregular ink application. He is guided by the checklist formed by items (a) to (f) above. The deviations noted are stated on the examination sheet, if possible indicating one or more causes as stated under (a) to (f).

11.6.4. Recording deviations in the distribution of the ink

All deviations can be described in principle. However, in a number of cases of sketched characters may be used for which the divergence is indicated.

The following conventions have been agreed on for the situations mentioned:

- situation (a): the part of the character not covered with ink is indicated in the sketch by a dotted line;
- situation (c): the *"soiled"* part of the sketched character is shaded or indicated by a pattern of dots;
- situation (d): the part of the sketched character containing more ink is thickened with a pen or pencil.

11.6.5. Deviations caused by "dragging" or "jolting" of the writing element

The print of a character is not sharp and unambiguous if the writing element remains pressed on the ribbon too long and the carriage or element is already being moved. This is called "*dragging*".

A character may also be printed several times when the writing element "*jolts*" repeatedly on the paper after a strike and the carriage or writing element is shifted at the same time. This deviation is due to a malfunction in the mechanical part of the typewriter.

The extent to which these deviations are visible depends partly on the actions taken by the typist.

Deviations of this kind occur mainly in typewriters with type bars.

It is often difficult to say whether the deviation in the print is due to "*dragging*" or to "*jolting*" of the writing element. If the writing element "*jolts*", it is often stated that the character is printed double or drags.

The examiner must check which characters in the typescript to be examined *systematically* jolts or drags.

11.6.6. Recording deviations as a result of the writing element "dragging" or "jolting"

All deviations can be described in principle. Use can also be made of a sketch of the characters concerned in which a shadow line is drawn to the right or left of the character.

11.6.7. Other characteristics

If the examiner notices a characteristic other than those mentioned above, he will state this clearly on the examination sheet.

11.7. Comparison of typescripts

11.7.1. General

In first instance, the general machine characteristics of the typescript of the documents under examination are compared. If they correspond or do not conflict with each other, any machine-specific characteristics that may be present are compared. Finally, the conclusion is drawn and the results of the investigation noted on the examination sheets.

11.7.2. Comparison of general machine characteristics

The general machine characteristics can be divided into two components, namely:

- the character distance or pitch and the letter type class. These are determined for both the typescript regarded as questioned and the reference material as stated in 11.2, 11.4 and 11.8. If these characteristics do not coincide, the documents have **not** been prepared with the aid of the same typewriter or the same writing element. If they do coincide, or if they do not conflict, this is stated on the examination sheet and the form and dimensions of the characters are compared.
- the form and dimensions of the characters. The form and dimensions of the characters are examined for visual equivalence by a trained expert. Forms are visually equivalent if

they coincide fully on projection at equal enlargement. An experienced examiner ascertains this equivalence by a visual check with or without the aid of a measuring lens, stereo-microscope or comparative measuring microscope. The examiner indicates similarity for each character on the examination sheet. As soon as he notes a difference, no further check is then necessary. If the shapes do not coincide, the documents were **not** produced with the aid of the same typewriter or the same writing element.

11.7.3. Typewriter-specific characteristics

Ascertaining typewriter-specific characteristics

Typewriter-specific characteristics of the typescript of the documents concerned are ascertained in the way described in 11.5.

Comparison of typewriter-specific characteristics

The typewriter-specific characteristics found in the typescript on the documents are compared visually with each other by a trained expert. The examiner uses a measuring lens, stereo-microscope or comparative measuring microscope to do so.

The typewriter-specific characteristics may coincide, not conflict or differ. The characteristics coincide if they are equivalent. The characteristics do not conflict if the difference in equivalence does not conflict with the passage of time between preparations of the documents. If documents have been produced on the same typewriter or with the same writing element, at least the same damage must be found in the document typed later as in the document typed earlier. Since damage may expand in the course of time, more damage may possibly be found in the document produced later or damage may be found to be covering a larger area than the damage in the document. Deviations are similarly variable by nature. Certain deviations can be quite easily repaired. The expert must take this into account when comparing deviations.

If the typewriter-specific characteristics differ and this cannot be explained by the passage of time between preparing the documents, the documents were **not** produced with the same typewriter.

The similarities/differences found are noted by the examiner on the examination sheet.

11.8. Examination of photocopied typescript

11.8.1. The- photocopied typescript

The following situations may occur with photocopied typescript:

- Photocopies are made without using the facilities for enlargement or reduction. The typescript is then generally slightly enlarged, but sometimes reduced. In practice, the reproduction factor under these conditions is generally no greater than 1.02 and not less than 0.98. Under the conditions outlined above, it is not possible to distinguish this from

the cases where enlargement or reduction was intended, but where a reproduction factor was selected between 0.98 and 1.02;
- The photocopy is made by using the adjustments to enlarge or reduce it. One of the default enlargements or reductions or a non-standard adjustment may be adopted.

Typescript in photocopied form is treated in principle, according to the procedures above, as if it has not been enlarged or reduced, unless the contrary is obvious in the light of the criteria described below. When comparing the characteristics of photocopied typescript, the examiner must either allow for greater inaccuracy in the values measured, or treat the measurements concerned as if they cannot be determined.

All observations are noted on the examination sheet.

11.8.2. Checks for enlargement or reduction of photocopied typescript

From the list mentioned below, the examiner makes a number of checks to determine whether the typescript has been enlarged or reduced. The reproduction factor is calculated where possible.

- The character distance is measured in accordance with 11.4 as if it concerns original typescript. The measured value is compared with those that occur in practice. The character distance of typescript normally has a value of between 1.69 and 2.72 mm (see Table in 11.2.2). Should the measured character distance of the photocopied typescript lie outside the stated area or not around a value appearing in the table (e.g. 2.42), the photocopy contains typescript which has apparently been enlarged or reduced.
- A check is made whether the typescript complies with the characteristics of letter type classes "pica" or "elite", as described in 11.2, ignoring the letter dimensions. The character distance and the capital letter size are measured as if an original typescript were concerned as mentioned in guidelines 11.4 and 11.2.
- If the shape of the letters indicates that the letter type class is "pica" or "elite", but the measured character distance in combination with the capital letter size does not correspond to the values associated with these classes, the photocopy contains typescript that has apparently been enlarged or reduced.
- The line distance is preferably measured between two characters situated vertically beneath each other using a measuring lens or the comparative measuring microscope. The line distance measured can be compared with that occurring in practice. The line distance is generally 4.23 or 4.25 mm. By appropriate use of the line shift mechanism, whole and half multiples of these quantities can be found (1.5, 2, and 2.5). In addition to the frequently occurring quantities of 4.23 mm and 4.25 mm, other distances also occur, albeit less frequently, which are virtually no smaller than 3.7 mm and no larger than 4.56 mm or whole or half multiples of these.
- Clear deviations from the standard range of values for line distances may where they occur provide an indication of enlargement or reduction and on the reproduction factor associated with it.

- Look for possible "margins" on the photocopy as a result of a reduction. When a document is reduced, blacking may appear at the edges of the photocopy. If this is visible, the photocopy possibly contains reduced typescript.
- Comparison of the photocopy with reference material. This includes amongst other things:

  - original typescript on an original document belonging to the photocopy, e.g. a typed address on an envelope;
  - characteristics inferred from the print;
  - characteristics inferred from the reference material such a postage stamp, a postmark, or the image of a staple or paper clip;
  - other reference objects applicable in specific cases.

- Comparison in the form, character distance and capital letter size other than for letter type classes "pica" and "elite" as indicated under (d). The characters of the photocopied typescript are then compared with those in the classification systems.

Only if the examiner, applying the above checks, finds indications of enlargement is this mentioned on the examination sheet. Where possible, the reproduction factor is calculated. This is defined as:

RP = <u>distance measured on the photocopy</u>

(corresponding part on the reference object (including the classification systems).

If after making the above checks, the examiner finds no indication of enlargement or reduction but still has doubts in this area, the characteristics concerned are treated as if they were not able to be determined.

11.8.3. Determining character distance and letter type class in documents with photocopied typescript.

<u>If no indications are found of enlargement or reduction:</u>

If the checks made under 11.8.2 have provided no indications of enlargement or reduction, the character distance and dimensions are determined in the way described in procedures above, concerning the original typescript.

If the character distance lies between two adjoining quantities on the grids, these parameters are noted on the examination sheet. The cluster or clusters in which the character distance lies is noted down as provided in 11.4.

The character distance is measured with the comparative measuring microscope in accordance with 11.4 if examination using the grids indicates that the value of the character distance lies in an area for which no grids are available.

The size of the capital letters is determined with the measuring lens in accordance with 11.2.

<u>If there are indications of enlargement or reduction:</u>

Should the photocopy be found to contain enlarged or reduced typescript, the character distance and letter type class can be determined only if the reproduction factor can be calculated. The character distance in the original document is equal to the measured character distance divided by the reproduction factor. The letter dimensions are calculated in the same way.

The examiner will take into account the margin of error that may arise as a result of measurements and calculations.

11.9. Examination of typewriter ribbons

11.9.1. Fabric ribbons

Only in exceptional cases is it possible to examine fabric ribbons. Fabric ribbons that have been written on only once can be read under certain circumstances. For ribbons inked in two colours, the text written with the second colour may under certain circumstances be read thanks to the remainders of the main colour that the types leave on the second colour zone as they strike. By comparison with the written text on the paper, the colour changes may help to identify a ribbon with a text.

11.9.2. Carbon ribbon examination / paper fibre transfer

It is usually possible to reconstruct the text typed with a single-use carbon film ribbon or thermal transfer ribbon from the ribbon.

11.9.3. Used carbon ribbon

It may in certain cases furthermore be possible to prove whether a seized ribbon can be associated with a document or a type carrier. Several methods can be used for this purpose:

- Comparison of the individual characteristics of the print
- Comparison of corrections
- Paper fibre transfer examination, and
- Comparison of tear-off edges

<u>Comparison of the individual characteristics of the print</u>

If the print has individual characteristics, these may under favourable conditions also be detected on the ribbon used. Together with the methods indicated above, this may serve as evidence to prove whether the questioned document has been written with this, and only with this, particular ribbon.

Comparison of corrections

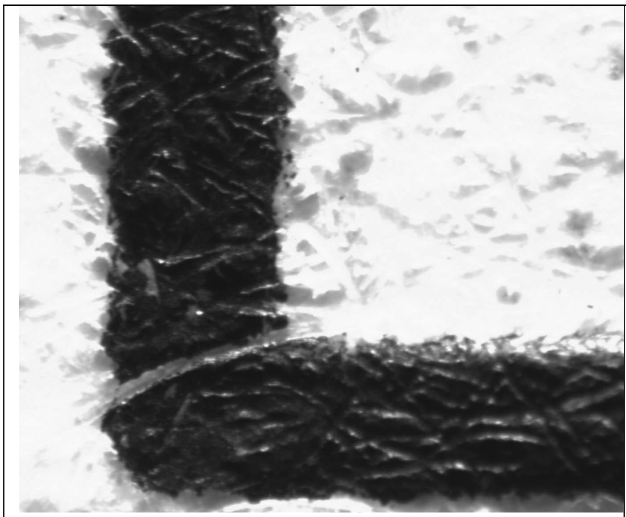
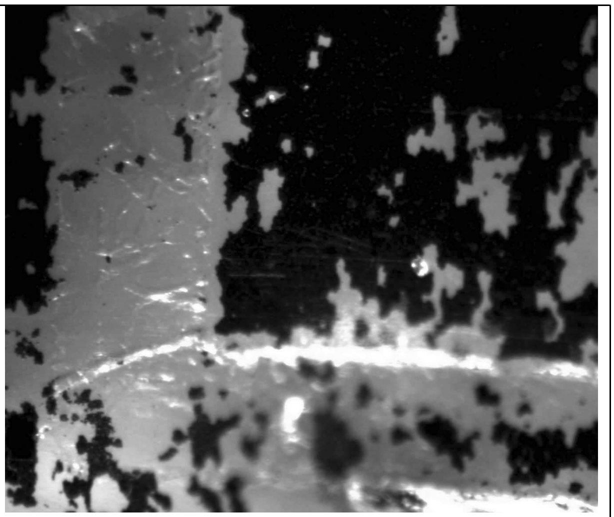
Depending on the method used for corrections (lift-off or cover-up), it is possible to correlate the corrected typing mistakes to the images on the coloured ribbon. On the line illustrated above, the first part of the word "PERSONENKRT" was changed with lift-off correction material to read "PERSONENKRAFTWAGEN". For this, the letter "T" was struck twice (highlighted in red), the first time as a typing mistake and the second time in order to lift off the letter typed by mistake with the correction ribbon.

In the case of typewriters with a lift-off correction ribbon, the characters typed by mistake can be retrieved both from the coloured ribbon (twice) and from the correction ribbon.

It is frequent that when documents, for instance, identity documents, forms, etc., are filled in, the text is at first typed into an incorrect position and the character is therefore deleted again.

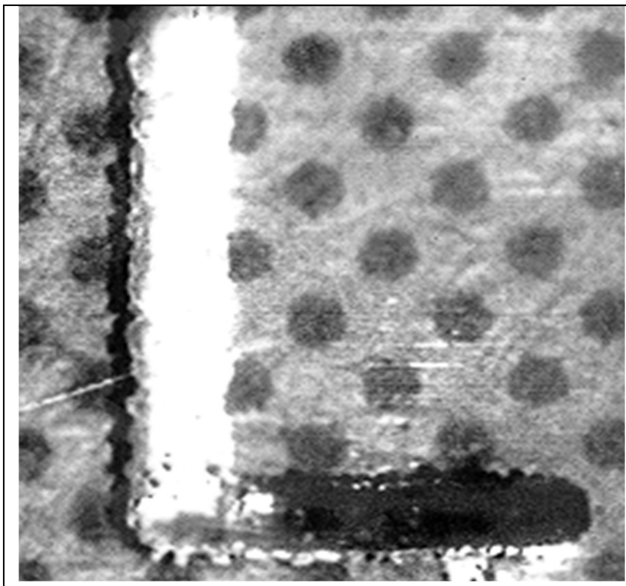
Paper fibre transfer examination

As a result of the pressure exerted by the typeface as it strikes, part of the paper fibre design is transferred to the ribbon backing. Using appropriate examination methods such as reflected light, transmitted light, or polarisation microscopy, or combinations of these, it is possible to make the image of this fibre structure on the ribbon backing visible. By comparing this image to the corresponding part of the paper, it is possible to prove whether the character has been typed with this, and only with this, particular ribbon.

	
Text on a passport	Corresponding part of the carbon ribbon

<u>Comparison of tear-off edges</u>

Single-use carbon film ribbons allow comparison of the tear-off edges of the characters on the carbon ribbon with the edges of the characters on the paper. It is noteworthy that bits from the carbon ribbon may become detached from the ribbon, but are not necessarily transferred to the paper.

	Picture of the imprint on the ribbon placed over the printed character "L". The comparison of the edges shows that the character has been typed with this, and only with this, particular ribbon.

11.10.Reinserted documents

11.10.1. General

In order to determine whether a typewritten document has been created during one or several sessions, it is generally examined whether the document shows any signs of having been reinserted into the device.

If a document has been created in a single session, the characters are largely arranged in parallel rows and columns.

If the paper is readjusted inside the device while the document is created, for instance, if the platen is released or the document is inserted into the device again in order to amend or correct it, characters may be misplaced due to horizontal or vertical misalignment.

If it has been possible to identify any such misalignments, this proves that the document has not been created during a single session or has been inserted into the device more than once.

11.10.2. Conventional Measuring Grids

Previously, once the systems had been established to be identical, special measuring grids were used to examine whether the aforementioned horizontal or vertical misalignment was present. A disadvantage of this method is that in principle a specific grid must be at hand for each character and line spacing possible. The considerable cost for acquiring all these grids is not the only reason that makes it impossible to have a collection of all the grid widths required.

The various line spacings, in particular, cause difficulties. In principle, the line spacing is determined by the typewriter mechanism. In practice, however, line spacing varies due to different paper thickness, manifold sets and multipart form sets. It is feasible to have a collection of grids for the most common character spacing values (2.12; 2.54; 2.60), but it is impossible to do so for line spacing.

This problem can be solved with the help of electronic image processing, since this allows for grids to be generated for any spacing desired.

11.10.3. Digital Measuring Grids

First, the questioned document is scanned to produce an image of it on a computer. 400 dpi resolution is sufficient for this purpose.

"Adobe Photoshop" or another image processing program is available to many forensic laboratories. The present work uses "Photoshop 5.0".This program contains a "Line Drawing" function with which any desired grid can be created on the scanned image. This makes it possible to examine nearly any character and line spacing.

- The digitized questioned document is positioned in such a way that at least one column is vertical to the image axis.

- A vertical line is created in the character-free part of the document, a line width of at least 3 and at most 5 pixels is recommended. This line is selected with the "Magic Wand" tool and copied into the clipboard.
- The "Insert" option is used to copy the vertical line into the image as many times as desired.
- This method creates a column testing grid.
- The same steps can serve to create, copy and paste a horizontal line, thus creating a line testing grid.

For the following example, a sheet of paper was inserted and typed on twice in a daisywheel typewriter. The upper part of the text was created during a first session, then the sheet of paper was removed from the device. For the second session, the paper was reinserted into the device by use of the automatic paper feed and the lower part was typed.

	During a first step, the document is examined for horizontal misalignment. It is apparent that the characters in the lower part of the text are not arranged along the columns of the characters in the upper part.

	During a second step, the document is examined for vertical misalignment. While in the lower part of the image the lines are in parallel with the baseline, they clearly diverge in the upper part.

11.11. Dating of a typewritten document

In certain cases, a typescript examination can serve to determine the time when the document was created. As a result of the system identification, it is generally also known when the typeface or variant in question was introduced into the market. Thus, a document dated before the market introduction will have been proven to show a wrong date. If the date on the questioned document is posterior to the market introduction, it is not possible to conclude on the genuineness of the date through this method.

It is possible to relatively determine the date when a document was produced if

- the print shows individual characteristics;
- it is possible to identify the typewriter based on the individual characteristics;
- the individual characteristics have changed with the course of time;
- enough material is available for comparison that is known to be from the period in question.

If all this is true, the changes in the individual characteristics can serve to delimit the period of time during which the document was created. The identification of the period in question will depend on the intervals between the various comparative samples and the changes in the individual characteristics.

12. RECORDING AND INTERPRETATION OF RESULTS

12.1. Quality of the submitted materials

Either the material to be examined is available in a form that allows unrestricted examination, or the material may have some properties that infringe on the examination.

The report should make notice of all properties that have a negative impact on the examination, for instance:

- Photocopied material is submitted for examination.
- Text passage is too short.
- The quality of the material submitted for examination is low.

12.2. Assessment of the findings and conclusion

The evidentiary value of typescript characteristics depends on several parameters:

- the kind of individual characteristics: Typeface or alignment defects, or a combination of both;
- the nature of the characteristics: device design, character damaged, kind of damage, location of damage;
- the number of characteristics.

It must be noted as a general rule that a characteristic may only be considered for the assessment if it occurs in the same fashion wherever the character in question occurs in the text examined.

If the characteristics show dissimilarities, it must be examined whether particular circumstances, such as handling errors, the paper, ribbon, or influences of the copying mechanism, are possible causes for this.

If no explanation for the dissimilarities can be established, this characteristic feature cannot be considered in the conclusion!

12.2.1. Typeface defects

These have a relatively high evidentiary value since the original typeface cannot be restored at least in traditional typewriters. The defect can only be repaired by replacing the damaged types. It is, of course, easily possible to replace the golf ball head or daisywheel in golf ball head or daisywheel typewriters. It is theoretically feasible to replace damaged types in type bar typewriters, but this is very unlikely to be common practice due to the high effort required.

In many cases, the user will not even realise that there is a defect, if it is only possible to identify the defect thanks to a direct comparison with an undamaged type by metrological examination.

The defects must be assessed both individually and as a whole. It is not rare for typefaces with serifs to have damaged serifs on certain types. It is very common that the serifs of the minuscules "n", "m", and "h" are damaged.

In these cases, it is important to correctly assess the nature of the damage. Only if the characteristics found in these characters are very pronounced, they may be considered to have full value. If there are characteristics in characters that are in general rarely ever damaged, or if characters are damaged in places where damages do not usually occur, then these characteristics must of course be considered to have a higher value.

12.2.2. Alignment defects

These need to be assessed in a particularly meticulous manner to determine their usability.

It may be necessary to assess not only the individual characteristics, but also all the circumstances that may have influenced the production of the items examined such as the design and age of the devices, make (if known), amount of time passed between the creation of various documents etc.

Misalignments most frequently occur with type bar typewriters. Unfortunately, however, it is very difficult to establish the cause of these misalignments. If there is unequally distributed vertical misalignment of characters, this may be due to a defect in the segment or in the interplay of segment and platen. If vertical misalignment occurred in relation to the case shift mechanism, this may be due to a defect of the device or due to improper handling by the user. It is therefore necessary to assess in each case whether the features established are appropriate for identification.

12.2.3. Remarks on assessment

There is no rule that would define a minimum number of characteristics sufficient for identification. An uncommon, particularly pronounced feature in an uncommon location may, in an extreme case, be sufficient, whereas a whole range of very common characteristics may not be sufficient for identification.

The assessment of the characteristics surely contains a large amount of subjective judgement by the expert. The expert's experience plays a major role: The more typescript and thus the more characteristics an expert has had a look at and has assessed, the firmer his judgement will be. But even the assessment by an expert with a large amount of experience will be a subjective judgement.

12.3. Probabilities

For an identification "with certainty" it would be necessary to know and assess all the devices with the particular font established in this case. This is, in general, not possible. Therefore, the results are expressed in a degree of probability that cannot be translated into a numeric figure.

There are too many unknown variables for a numeric classification. It is usually not possible to find out how many devices have definitely been produced, how many of these create the characteristics, how and for how long the devices are used, how they are maintained etc.

As a general rule, the assessment of the findings of a typescript examination will be expressed by a degree of probability that cannot be numerically quantified. Practice shows that these degrees of probability are used in very different ways.

As can be expected, the problems arise for the low degrees of probability, since in these cases it is most difficult to assess the set of characteristics observed. Consultations with other authorities on the degrees of probability used have shown that they even use different terms in these contexts, whereas the verbal descriptions are largely identical for the high degrees of probability.

During an expert meeting at a national level, the "Symposium der Maschinenschriftsachverständigen", celebrated in Dresden, Germany in May 2001 the experts defined a graded list of degrees of probability to be used by all typescript examination experts nationwide. This list will be presented here as an example:

All the degrees of probability concerning the comparison of one or several typescript documents with a typewriter are based on the fact that they have been found to be of the same system.

Belonging to the same system means that the basic forms of the characters, character spacing, line spacing, character-to-key assignment and motion (for type bar typewriters only) of the typefaces under examination are identical.

If the typefaces are not associated with the same system, it can be excluded right from the beginning that they might be identical. In this case, it is superfluous to assess the probability.

The following possible statements were decided on:

- With a probability bordering on certainty

The material must have been fully adequate for analysis. The same individual characteristics have been found in all the exhibits examined. Due to their number, nature and/or infrequency, these characteristics have such a high evidentiary value that it is unimaginable that there might be a second device within the set of devices in question that might show the same characteristics. There is no reasonable doubt that the exhibit examined and the known reference material originated from one and the same device.

- With a very high probability

The characteristics established during the analysis have a very high evidentiary value. However, there are limitations that do not allow an identification with a probability bordering on certainty. These limitations may be caused by the nature of the exhibit (for instance, low-quality imprint of the types, photocopies submitted for examination, insufficient amount of text) or may be due to the number, fashion and/or frequency of the characteristics.

- With a high probability

The characteristics themselves do not have a high evidentiary value or there is an insufficient number of them and/or the nature of the exhibits does not allow the results to be classified under a higher degree of probability. However, based on previous experience, it is rather unlikely that there should be a further device with identical characteristics.

- Probable

The individual characteristics considered one by one do not have a high evidentiary value or the material has not been fully adequate for analysis. However, the overall assessment of the findings supports the conclusion of identity rather than speaking against it.

The following conclusions do not fall within any of these degrees of probability:

- For lack of individual characteristics, neither excluded nor established as being identical

If the general characteristics are found to be identical, the examination tries to establish whether there are any individual characteristics beyond the identical system/class characteristics. If no such individual characteristics have been detected, it is not possible to determine whether the devices are identical or cannot be identical.

- Classification or identification not possible due to inadequate material

If the assessment of the material shows that the material is inadequate for the examination requested, no conclusions can be drawn in terms of a classification or identification.

- Not identical

If the analysis shows that the exhibits belong to different systems or classes, it is excluded that they may be associated. Furthermore, if the individual characteristics are found to be different in a way that cannot be explained in terms of a normal modification of the characteristics over time, identity is also excluded.

All of the above are generalised definitions, the findings in each case need to be specified in detail.

13. QUALITY ASSURANCE AND COMPETENCY

All results that are open to interpretation should be checked by an independent examiner.

14. BIBLIOGRAPHY

- D. Ellen, “The Scientific Examination of Documents: methods and techniques” Ellis Horwood Limited, 2nd edition 1997, ISBN: 0748405801;
- “The Story of the Typewriter 1873-1923”, Book, Herkimer County Historical Society, Herkimer, New York, 1923;
- J.E. Behrendt and R.J. Muehlberger, “Printwheel Typescript Variations Caused by the Manufacturing Process”, Journal of Forensic Sciences, Vol. 32, No. 3, May 1987, p. 629-639;
- M. J. Allen and R. A. Hardcastle, "The Distribution of Damage Defects Among Characters of Printwheel Typing Elements", Forensic Science International, 47, 1990, p. 249-259;
- J. Nemecek, “A Deep Look into Typewriter Alignment”, Journal of Forensic Sciences, Vol. 10, No.1, January 1965, p. 23-34;
- E. Kube, H.U. Störzer & K. Timm (Hrsg.), (1992 u. 1994), Kriminalistik, Handbuch für Praxis und Wissenschaft, Bd. I u. II, Stuttgart, Boorberg-Verlag, ISBN: 3415015068;

- M.J. Allen, and R.A. Hardcastle, “ A classification scheme for Courier typestyles” , Journal of the Forensic Science Society, Vol. 30, No. 3 (1990), pp. 137-142;
- H.J. Shalley, “The association of lift-off tape with residual ink fracture outline by physical matching”, Canadian Society of Forensic Science Journal, Vol. 27, No. 2 (1994), pp.59-67;
- J. A. Blanco, “Identifying Documents Printed By Dot Matrix Computer Printers”, Forensic Science International, 59 (1993) 35-47;
- M.W. Arbouine and S.P. Day, “The use of drum defects to link laser-printed documents to individual laser printers”, Journal of the Forensic Science Society (1994) Vol 34. pp. 99-104;
- R. S. Winter, “The Detection of Laser Printer Defects for Printer Identification”, Presented at the Annual Meeting of the American Society of Questioned Document Examiners Ottawa, Canada - August, 2000;
- Buglio. J., "Association of Document and Laser Printer by Means of Residual Toner Impressions," International Journal of Forensic Document Examiners, Vol. 5, Jan/Dec 1999, pp. 365-370;
- S.F.Pond, “Inkjet Technology and Development Strategies”, Torrey Pines Research 2000;
- S. P. Day, L. Shufflebottom, “Evidential Value from Ink-Jet Printers”, presented at the 2nd EAFS meeting, Krakow, September 2000;
- W. L. Rosch, “Winn L. Rosch’s Printer Bible” MIS Press 1996, ISBN: 1-55828-436-2;
- H.P. Le, “Progress and trends in Ink-jet Printing Technology”, Journal of Imaging Science and Technology 42, 1998, pp. 49-62;

APPENDIX 9 – OVERVIEW PROCEDURE FOR EXAMINATION OF STAMPS AND STAMPS IMPRESSIONS

1. INTRODUCTION

A stamp is an impression-producing device commonly used for imprinting signatures, dates or company addresses on documents. The name “rubber stamp” may be used to refer to those with printing areas made of rubber or polymer whereas “seal” to those made of stones, ivory, wood etc. that are commonly used in Asian countries. Whilst the majority of “rubber stamp” has the printing area in relief, seals could have the design in relief or in recess.

Stamps and stamp impressions are often counterfeited to try to demonstrate that some official approval has been given to a particular action or transaction. False Stamp Impressions may be found on such documents as passports and other travel documents, cash books or money orders, bank documents, permits to import or export goods etc. Official stamps are often manufactured using rubber, photo-polymer or metal and will often have a very specific purpose. Consequently, there are commonly only a small number of official stamps in existence at one time and their use is often restricted to one or a small number of individuals. Determining whether a stamp impression is genuine or counterfeit can therefore assist an investigator to establish whether a crime has been committed and, if so, the way a crime has been carried out, especially if the impression can be linked to a particular stamp.

The examination procedures most suitable for the examination of a particular stamp or stamp impression will depend on the materials available for examination and to some extent the circumstances of the case. Techniques will include a visual and microscopic examination of the material, filtered light examination and some form of overlay procedure. Analytical techniques may also be needed and should be available. The analytical techniques lie outside the scope of this document.

2. SCOPE

All cases where the questioned document bears a stamp impression which is to be compared with either a stamp to determine if that stamp made the impression or with other stamp impressions to determine whether they share a common origin, or to determine the date that the impression was made. It does not include the analysis of inks, which is dealt with separately.

3. PRINCIPLES

Comparison of stamps or stamp impressions is usually carried out through a visual and microscopic examination and comparison of the submitted material. This will usually involve the super-position of images taken from one item onto those of another. Occasionally other techniques may be required, depending on the material to be compared.

The examination will be more effective if the stamp thought to have made the questioned stamp impression is available for inspection. If available, it is crucial to inspect the genuine stamp or stamps that the questioned stamp is designed to imitate so that it can be eliminated as a possible source and also to establish how a counterfeit stamp has been made.

Occasionally it may be useful to compare the chemical composition of the ink used to make stamp impressions, either with each other or with the ink present on a particular stamp (questioned or genuine).

Whilst most stamp pad ink is in liquid form, ink for seals could be in the form of paste. For instance, the red seal paste commonly used in Chinese seals are cinnabar, or mercury sulfide, pulverised and dispersed in oil.

It may also be useful to compare the chemical composition of the rubber or photo-polymer of two or more stamps. The techniques for this are outside the scope of this document and are not described here.

To be able to give the correct scientific weight to the evidence found it is necessary to have a good understanding of the methods of manufacture of the stamps involved. Suitable background references are the books mentioned in section 12.

4. GLOSSARY

Bullseye - Small dark spot surrounded by a white, uninked circle in an otherwise inked area caused by a piece of debris adhering to the image surface of the stamp. Also known as a “hickey” in printing terms.

Cushion - Usually a foam cushion is glued between the mat and the mount to produce a uniform and even printing pressure. Stamps mounted without a cushion are difficult to use because they require greater effort to align the stamp and the surface of the paper.

Die - The printing surface of a stamp that bears the design intended to print. [Can also be defined as the shape which is pressed into the matrix to form the mould.]

Mat - The part of the stamp that supports the design. The mat is always larger than the image and therefore has to be trimmed. It is not intended to be inked but is frequently and produces characteristic extraneous marks. Mat trimming is often done by hand and therefore can have a characteristic profile.

Riser - The surface of the rubber that leads from the printing surface to the mat face. This is generally diagonal or vertical. It is frequently inked by over-spill action of the ink pad but is not intended to print.

Self-inking stamp - A stamp with a built in ink pad and a mechanism to transfer ink from that pad to the stamp every time the stamp is used.

Pre-inked stamp – A stamp with the die typically made with gel or laser foam where ink is encapsulated or impregnated into the material and will be released on the imprinting surface upon applying pressure on the stamp.

Stamp - Any instrument bearing an image on a die either in relief or flat.

Stamp impression - Any impression made by an inked die or embossing stamp.

5. CROSS REFERENCES

- Ink Analysis by TLC
- Examination of Intersecting Lines

6. PRESERVATION AND HANDLING OF ITEMS

Stamps seized by the investigator should be protected from damage by packaging in secure plastic bags, envelopes or, preferably, boxes. The printing surfaces should be prevented from rubbing or striking other items.

It is the responsibility of the examiner to ensure that the most appropriate samples for the examination are supplied for the question that is posed, in consultation with the investigator or client. Inappropriate sampling may alter the stamp permanently.

The examiner should ensure that they are in possession of all relevant knowledge about the circumstances of the case and the manufacture of the stamps. For example it may be useful to know how many genuine stamps of the same general design as the questioned exist.

A visual and microscopic examination of the stamps should be carried out before any sampling is undertaken.

7. EQUIPMENT/INSTRUMENTATION/OPERATING CONDITIONS

- Magnifying glass or stereo microscope and light microscope
- Various light sources for direct, oblique and transmitted light
- A method for overlaying images such as a digital frame-store, comparison microscope or facility for making transparencies such as a photocopier, photography or calibrated reproduction equipment. If a photocopier is used care must be taken to ensure that any distortion to the image caused by the photocopying process is taken into account.
- Oblique light

- An instrument for examining items under filtered light, particularly in the infra-red and ultra-violet.
- Photo-editing software to facilitate effective comparison between questioned and specimen impressions.

8. REAGENTS AND MATERIALS

- Ethanol
- Cotton swabs

9. HEALTH AND SAFETY

Outside the use of solvents to sample the inks, there are no particular Health and Safety issues involved in the examination of stamps and stamp impressions.

This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

10. PREPARATION AND CALIBRATION OF EQUIPMENT AND REAGENTS

Not applicable.

11. PROCEDURE

11.1. Examination of a Stamp

The examiner must first examine the stamp visually. If the basic design (proportions, size, fonts, layout of letter, numbers etc.) does not resemble the questioned impressions then no further examination is necessary. If no stamp is available, then the procedure described in 11.4 should be followed.

The stamp should be examined in detail before making any test impressions to determine whether any defects are present in the form of damage. Notes should indicate where any features are found, and these should include photographs where appropriate.

Examples of features to look out for include:

- Progressive features such as cracks, dented surface or damages;
- Characteristic features such as uneven surfaces due to hand carving.

Undesirable features such as air bubble or spot found in mass-produced stamps may not be specific or individual to one single stamp. Their presence could be attributed to the air bubble on the mould or the spot on the negative of the film, both of which are used in mass production of stamps.

A note should be made of the colour and type of ink for which the stamp has been used previously.

11.2. Test specimens

The examiner should attempt to make a specimen impression without inking the stamp so that a record is made of the ink on the stamp in case any future comparison is requested. If the stamp is completely dry, the examiner may consider swabbing a small area with a suitable solvent (alcohol for most rubber stamp inks) to retain a record of the ink present, being careful not to interfere with any characteristic features. This procedure will not usually apply to self-inking stamps unless the inking mechanism has dried up or if the pad has been removed.

Test impressions should be made using a clean stamp pad in good condition, preferably on paper similar to or the same as the paper containing the stamp impressions to be examined. Impressions should also be made on papers of different quality as some features visible when using a thick paper are not visible when the stamp is applied to a thin paper. The texture of the surface of the paper can also affect the way the stamp is reproduced. The examiner may need to try different types of ink pad, for example, felt, cloth covered felt, gelatin, stone etc., before obtaining specimens suitable for comparison with the questioned ones. Self-inking stamps will not require a pad unless they have dried up or the internal pad has been removed.

The type of ink used has to be compatible with the materials that the stamp die is made of. For hand stamps made of rubber or photopolymer, liquid-based ink could be used; for industrial-use stamps that are usually made of synthetic rubber such as nitrile rubber, oil-based ink may be used.

Test specimens should be made with varying degrees of ink and pressure. Several impressions can be made without re-inking the stamp. A lightly stamped impression may show different features from a heavily stamped one. If the questioned impression shows evidence of distortion or rebounding, the examiner should try stamping the test impressions in different ways in order to see if the effect can be reproduced. Using a rolling method from one side to the other (or top to bottom) both in inking and stamping may help to reproduce extraneous marks from the mat, cushion and mount, however, extra caution has to be exercised to avoid damage to the stamp.

If it proves difficult to make test impressions which are fully inked, it may be because the surface on which they are being made is too hard. This is a particular problem with metal stamps and some counterfeit stamps that are mounted directly onto a handle with no cushion. The examiner can try putting some padding under the paper such as layers of tissue, piles of paper or thin foam.

Stamps that are unmounted can also be a problem. The examiner may find attaching a temporary mount (e.g. plasticine) useful. Impressions made with and without a mount can differ in appearance.

Adjustable and composite stamps, such as date stamps and single-character-kits, designed to be used in different combinations, should be moved to the combination which matches the questioned impression (having first made a note of the original setting). There is usually some flexibility in the positioning of the parts of the stamp, and the examiner may have to experiment with this in order to produce suitable test impressions. Before making the test impressions, be sure to check that the relevant combinations have signs of usage (ink residue) and make a note of this.

11.3 Examination of stamp impressions

The Examiner should examine the questioned impression microscopically to verify that it is a stamp impression and not a simulation produced by lithographic, ink-jet or some other form of printing. If the document is a photocopy of a stamp impression it may be possible to make limited examinations as detailed in 11.4 below. It may also be useful to link a photocopy to other documents within the case or to a particular photocopier, but this is outside the scope of this document.

The date of the documents containing the questioned impressions should be recorded.

11.4 Comparison of stamp impressions

11.4.1. General features

If the stamp is unavailable and only other impressions are provided for comparison, it may not be possible to determine the cause of the features found. It will limit the strength of the conclusion if the features cannot be shown to be unique as opposed to being part of the mould or artwork.

The basic design of the stamp impressions being examined (whether questioned or of known origin) should be compared by superimposing it using transparencies, an optical comparison microscope or a digital image processor. If a difference is found and the examiner is satisfied that it is a design difference, then no further examination is necessary.

If the design matches, then a comparison should be made of any damage features or defects.

If the questioned impression is non-original, it may be a product of image manipulation of genuine impressions. The use of image-editing software will be helpful for effective comparison to be made.

The ink distribution of the impressions may sometimes provide clues to the type of stamp that have been used. If heavy ink saturation is noted and the ink is evenly distributed over the entire impression, it is likely that pre-inked stamp has been used.

11.4.2. Damage features

Cracks, dents, cuts or chips in the surface of the stamp may not get inked and thus cause a corresponding gap in the impression. Any such features should be noted by the Examiner and the cause of such features ascertained. Features, which are unique to the stamp, may allow conclusive identification of impressions made with that stamp. Features that are a result of faults in the artwork or the mould could be found on another stamp from the same source if such exists. Damage can occur at any time during the life of a stamp and therefore impressions made before the damage occurred will differ from those made after.

Air bubbles in the stamp are caused during vulcanisation of rubber stamps and can also be found in some moulded plastic stamps and photo-polymer stamps made using liquid resin. They appear as smooth, un-inked voids and are unique to any one stamp. Air bubbles could be introduced during vulcanization of both mould and die. If air bubbles are introduced during vulcanization of the stamp die, it will then be unique to one single stamp. However, if they are introduced to the mould that is to be used to produce many stamps, it will not be unique to one particular stamp.

During production of photo-polymer stamps errors may occur that will result in visible flaws or characteristics in the final stamp. Some causes of these flaws are the use of the wrong films in reproduction, wrong time of exposure of the photo-polymer, no or not sufficient exposure of the reverse of the stamp, wrong time of wash out of the photo-polymer, wrong time of hardening etc. All these may cause a feature in the stamp-impression made by this stamp, which will be unique to this stamp. On the other hand, if the flaw is present on the negative of the film and the negative is to be used to produce many stamps, the features will no longer be unique to one single stamp.

11.4.3 Wear Features

With use, stamps become worn. This is often seen as a rounding of the image edges. Lines can become thinner with a tapering or shortening of the characters. The combination of wear features will usually be unique. Stamps wear more quickly at the edge than at the centre.

11.4.4 Other defects

Debris such as dust, fibres etc., which has accumulated on the surface of the stamp, can cause extraneous marks in the impressions. These are often darker than the true image because some debris tends to absorb ink. Most debris will be unique to a particular stamp. Care should be taken when assessing infill of characters caused by debris as this can be quite common. Debris builds up over a period of time but can be cleaned from the stamp. Thus, differences in faults caused by debris can be found within impressions made by the same stamp over a period of time

Small, solid pieces of debris on the flat image surface cause a circular gap in the impression often referred to as a “bullseye”. These will give a unique impression but are often transient. The appearance of this feature depends on the material make-up of the debris and hence its compatibility to the ink. The mat, cushion or mount, if they become inked and make contact with the paper, will cause extraneous marks outside of the image area. The examiner should determine whether the mat has been trimmed by hand as the edge profile will then be unique.

If the artwork used for the stamp in question was copied from a genuine impression, then any characteristic features within that impression arising from faults in the genuine stamp may be reproduced. The Examiner should therefore ascertain whether such features are part of the actual stamp itself or have been copied. (Copied features may not be unique if more than one counterfeit stamp exists.) It may not be possible to ascertain this if the actual stamp is unavailable.

11.4.5. Ink

If two or more stamp impressions are present on the same paper it is possible to do a comparison of the ink using UV/VIS/NIR luminescence and/or the NIR reflection/absorption examination, taking into account the limitations of these techniques as mentioned in the appropriate methods.

These methods can also be used to check the inkpad for possible contamination by other types of ink.

If the stamps are not on the same paper, then chemical analysis of the inks by techniques such as thin-layer chromatography, HPLC or Raman spectroscopy is necessary if ink comparison is needed.

11.5 Embossing Stamps

The above principles can also be applied to embossing stamps.

11.6 Determining the date the stamp impression was made

Look out for defects that are progressive such as wear-and-tear patterns, ink accumulations, change in size or shape or transitory such as dust, paper fibres or other debris and compare them with impressions of known production dates.

Chemical analysis of ink may be useful if a particular dye or pigment is not available in the market before a certain time.

11.7 Limitations

Quality of stamp impressions relies on a number of factors including type of substrate, type of stamp pad, angle and pressure in stamping, type and quantity of ink and hardness or nature of supporting surface.

As such, it is possible that not all individual characteristics can be reproduced in every impression.

12. RECORDING AND INTERPRETATION OF RESULTS

In some cases, it may be useful to contact the manufacturer of the genuine stamp before making the interpretation.

Once the test impressions have been compared with the questioned impression and any characteristic features noted, the similarities and differences between them should be considered by the Examiner.

Usually, the propositions to be considered will be similar to the ones below, depending on the circumstances of the case:

- the stamp made the stamp impression (or the impressions were made by the same stamp if no stamp is available);
- another stamp derived from the same source made the stamp impression.
- the stamp did not make the stamp impression.

Sometimes two or three of the above propositions will be equally well supported by the observed facts, in which case an inconclusive opinion will be offered. In most cases one of the propositions will be better supported than the others and a qualified opinion can be offered. Occasionally the observed facts will allow two of the three propositions to be eliminated, in which case the remaining proposition is proved.

If a match is found including one or more features that are unique to the stamp, then a conclusive opinion will be reached that the stamp or an perfect copy of this stamp, possibly obtained from an impression of the stamp in question made the impression. If any features have changed in between then it may be possible to conclude that the stamp made the impression but not in its present condition.

If a match is found but only including class characteristics (such as those produced by design or through faults in the mould) then a conclusion will be reached that either this stamp was used to make the impression or another stamp derived from the same source if such a stamp exists. In the case of stamps of a specific design made for a particular purpose, such as ones composed of individual printing slugs, it is unlikely that another identical stamp would exist and a high level of opinion for association can be formed. In the case of stamps that are widely available, such as date stamps, it is more likely that another similar stamp may exist, and a lower level of opinion will be appropriate. Often the Examiner will not have sufficient information to be able to fully address this issue and will only be able to state that the stamp and stamp impression match, which will provide, at best, moderate support for association between them. This may also be the situation if the actual stamp is unavailable. Information about the availability of the design of the stamp may be provided by the court from other sources and this may influence the opinion of the court as to the significance of the scientific findings.

If differences are found in the stamp design or in the damage, wear or other defects and no explanation can be found to explain them (such as a difference in time) then it can be concluded that the stamp did not make the stamp impression. In other circumstances it may only be possible to conclude that the stamp did not make the stamp impression in its present condition.

The information given to the customer should state the strength of support for the view that the stamp did or did not make the stamp impression or the degree of association between the stamp impressions examined. The examiner should be explicit about what alternative scenarios exist that would also explain the findings.

13. QUALITY ASSURANCE AND COMPETENCY

A competent Examiner should be able to use the necessary equipment and whichever comparison method (optical or digital) that is available in the Institute.

The competencies relevant to the examination of stamp impressions are summarised in the document: "Competencies for European Forensic Document Examiners".

Test impressions should be preserved and any critical findings that lead to association or dissociation of stamps or stamp-impressions should be checked by an independent scientist.

14. BIBLIOGRAPHY

- "Rubber Stamp Examination- A Guide for the Forensic Document Examiner" by Gary Herbertson, Wide Line Publishing, Colorado.
- “Forensic Examination of Rubber Stamps – A practical guide” by Jan Seaman Kelly, Charles C Thomas Publishing, Springfield, Illinois, 2002, ISBN 0-398-07278-7 (hard cover), ISBN 0-398-07279-5 (paper back).

APPENDIX 10 – OVERVIEW PROCEDURE FOR NON-DESTRUCTIVE PAPER EXAMINATION

1. INTRODUCTION

The majority of questioned documents to be examined consist of handwritten, typed or printed information on paper, and therefore, a sizeable part of the document examiner's work should be the examination of the paper itself. There are two types of paper examination, destructive and non-destructive. The purpose of the non-destructive examination should be to find out as much as possible about the paper characteristics, which will enable the examiner to make a decision about its authenticity, or relationship with other documents, without effecting the document for any other type of examinations to follow.

The examination techniques covered will include visual examination, measurements, microscopic examination and examination under specialised lighting conditions.

2. SCOPE

All cases where paper items are submitted as part of the case and require some description or mention in the case notes.

All cases where paper needs to be analysed to determine its authenticity.

All cases where two or more pieces of paper need to be examined in order to determine the relationship between them. Physical fits and determining whether or not a piece of paper originated from a pad of papers will be considered.

All cases where the source of a piece of paper needs to be determined.

The examination methods covered do not include destructive techniques, chemical analysis of the paper or fibres or examination for indented impressions or dating of the paper.

3. PRINCIPLES

Paper is made from a pulp of water and organic fibres (most commonly wood but rag fibres are also used for high quality papers) put through various steps of drying and straining. Other ingredients can be added to determine the required finish of the product.

The vast majority of paper, including writing paper, newsprint and commercial stationery, is produced on Fourdrinier machines.

Security paper is generally produced on a cylinder mould paper machine.

Different fibre ingredients can be used to make different grades of paper.

The paper itself can be further protected by the addition of other features at manufacturing stage such as security threads, coloured fibres, luminescent fibres, planchettes and security inks.

On a Foudrinier machine watermark features such as line watermarks, chain lines and laid lines onto the paper may be imparted into the paper by the Dandy roll during manufacture. Shadow or continuous tone watermarks may be made on a cylinder mould paper machine by including wire moulds in specific positions in the paper sieve.

Comparison of the physical properties of two pieces of paper can be used to determine whether or not a questioned document is authentic or a forgery.

Comparison of a piece of paper with another piece of paper or a pad of papers can be used to determine whether or not the piece of paper in question originated from the same source as the pad or piece of paper.

Comparison of the cut or torn edges of two pieces of paper can be used to determine if the two pieces of paper were originally joined together.

Examination of certain physical properties such as the watermark or printed details on the paper can be used to determine the manufacturing source of the paper.

4. GLOSSARY

Chain lines - A series of parallel lines normally applied by the dandy roll to the felt side of the paper. Chain lines are normally applied 90º to the laid lines.

Chemical watermark - More correctly a papermark, the mark is a simulated watermark created by printing with inks, oils or waxes to produce a transparent effect on the paper.

Dandy roll - A roller used in the manufacture of the paper on a Foudrinier machine. The dandy roll may be covered with wire in a series of patterns and/or lines. These are pressed into the felt side of the wet forming paper, forcing the fibres apart, creating translucent impressions comprising watermarks, laid lines and chain lines.

Felt side - The side of the paper which is not in contact with the sieve during production.

Formation - The way in which fibres arrange themselves in the paper. Judged by the look-through appearance.

GRAMMAGE or BASIS WEIGHT - The weight of the paper in g/m^2. A variation of ±5% is usually tolerated by manufacturers.

Hilites **–** Very small particles of fluorescent pigments (100-250 microns), homogeneously distributed on the paper and strongly visible on both sides. They may be coloured or invisible under normal lighting conditions.

Laid lines - A series of parallel watermark lines usually applied by the dandy roll to the felt side of the paper.

Look through appearance - This is a description of the evenness of fibre distribution assessed by viewing the paper with transmitted light. It is also an assessment of opacity/transparency and any impressions produced by the dandy roll.

Planchette - Small circular pieces of paper (usually 1mm in diameter) incorporated into security papers. They can be coloured and may be UV fluorescent.

Ply - Paper strength can be increased by sticking several sheets together. The number of sheets used is termed the ply.

Security paper - A paper which incorporates one or a number of different features to bestow the paper with added security.

Security threads - Metallic or plastic strips inserted into the paper during manufacture. They may be underneath the paper surface or partly showing, giving them the appearance of being threaded through the paper. They may contain microprinting.

Watermark - A design or text created in the paper during manufacturing by locally modifying the thickness of the paper. Two main types may be distinguished: the line watermark which consists of light and/or dark sections and the shadow watermark that displays several tones, often with fluent transitions. A line watermark may be manufactured by hand, on a Foudrinier (with the dandy roll) or on a cylinder mould machine, whilst a shadow watermark is only made by hand or on a cylinder mould machine.

Web - The former on which the paper is carried through the processing machines during manufacture.

5. CROSS REFERENCES

- Application of Luminescence to the Examination of Documents
- NIR Absorption and Reflection Examination of Documents

6. PRESERVATION AND HANDLING OF ITEMS

All items submitted for examination should be properly protected, packaged and labelled.

All documents to be examined should be handled as little as possible. Latex gloves should be worn or tweezers used for handling.

Do not fold documents.

If any change is made to the document (such as numbering of pages or removing of staples), a note should be made of the change.

The examiner should always bear in mind that further examinations and treatments may need to be carried out on the document when he/she is finished with it, i.e. chemical analysis, fingerprint treatment or DNA analysis.

The exact procedures required should be clearly set out on the examiner's notes and the correct sequence of the examinations decided on prior to examination.

Avoid prolonged exposure of the paper to strong lighting as this can change the visible properties of the paper.

7. EQUIPMENT/INSTRUMENTATION/OPERATING CONDITIONS

- Handheld magnifier.
- Stereo microscope.
- Micrometer.
- A document examination workstation incorporating:

  - Long-wave ultraviolet light for visible luminescence,
  - Intense visible light source for IR luminescence,
  - Infrared light source for absorption and reflection,
  - Transmitted light source,
  - Oblique light source for examining indentations and embossing,
  - IR sensitive camera and monitor,
  - Comprehensive range of excitation and blocking filters,
  - A printer.

The document examination workstation can be combined within one instrument or consist of separate components. The system can be computerized so images can be stored for comparison and retrieval purposes.

A well-lit examination area is needed for the initial examination of the document, whereas some of the other procedures require dark room conditions. Viewing the document by daylight can often be useful.

8. REAGENTS AND MATERIALS

A black sheet of cardboard paper or plastic to use as an underlying surface for IR luminescence examination.

Fluorescence scale (eg. Ciba Geigy plastic cards).

9. HEALTH AND SAFETY

Protective goggles must be worn when working with powerful light sources such as lasers or Xenon lights.

Each piece of examination equipment should have its own relevant health and safety considerations, and the user must familiarise themselves with them before using the equipment.

Always consider the possibility that the document to be examined could be contaminated and handle with care accordingly.

This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determines the applicability of regulatory limitations prior to use.

10. PREPARATION AND CALIBRATION OF EQUIPMENT AND REAGENTS

Each piece of equipment used should be calibrated, if applicable, according to the usual maintenance schedule.

11. PROCEDURE

11.1. Visual examination

Good lighting should be used either from daylight or fluorescent tubes. The following observations should be made:

- Size of document; measure with a ruler calibrated in appropriate units, usually mm. To calculate the grammage divide the weight of the paper, measured to 0,01 gram by its area (g/m^2).
- Colour of document; the colour may be judged visually in daylight or may be measured using a microspectrofotometer.
- Presence of printed lines, margins or other printed features.
- Presence of punch holes, perforations, holes, tears, rips, staples, staple holes, adhesives, etc.
- Condition of paper (dirt, staining, creasing, evidence of wetting, etc.).
- Condition of edges (torn, straight cut, rough or serrated, presence of guillotine marks, etc).
- Folding; the sequence of folding can be recorded using shorthand notation, H (horizontal fold), V (vertical fold), e.g. HVV.

- Fibre direction; the fibre direction may be determined by quantifying the bending properties of the paper in both directions. The greatest bending occurs parallel to the general fibre direction.
- Any unusual surface texture (abraded, glossy).
- Presence security features such as coloured fibres, planchettes, security threads, watermarks, etc.
- Any unusual features.

11.2. Micrometer examination

Paper will often be of variable thickness across its surface. The paper should be examined to determine its average thickness. A digital micrometer with a flat beak can be used. Measurements (approximately 10) should be taken across the paper surface and an average calculated to determine the average thickness of the paper.

11.3. Microscopic examination

Examination under a microscope should reveal any unusual features in the paper surface. Abrasion to the paper surface can be seen or a feathering of the paper surface which is often a sign that the paper has been wetted.

A microscopic examination can reveal if the paper has been coated or polished.

A microscopic examination can also be carried out on the paper edges to determine if they have been ripped, cut or guillotined.

A microscopic examination may also reveal security features such as coloured fibres or planchettes not visible to the naked eye.

11.4. Examination under transmitted light

A strong transmitted light source can be used to view the fibre formation, watermarks, laid lines, chain lines, security threads, opacity and general ‘look-through’ of the paper. Any unusual features such as watermarks can be photographed or recorded on a flatbed scanner in transmittance mode.

Sometimes parts of the screen from the sieve on which the paper was made may be visible. A closer examination of this screen using a Fast Fourier Transform (FFT) filter may be helpful in comparing the source of different papers.

If a watermark is detected it must be determined if it is a line, shadow or a chemical watermark. A chemical watermark can often be distinguished from an original watermark by its fluorescence under UV-radiation or by locally applying a-polar solvents to the paper to dissolve the watermark.

If the watermark is difficult to determine, a radiographic image can be taken using a beta emitting C-14 source impregnated onto a methacrylate polymer sheet. Placing the watermark between the source and x-ray film for 24–48 hours should reveal the image of the watermark on the x-ray film. Strict health and safety protocols should be observed when handling the C-14 source and protective gloves and clothing should be worn.

11.5. Examination under oblique light

Using a fibre optic light source the paper can be examined using oblique light. This can reveal indentations, embossing or an unusual paper surface. Findings should be recorded and if relevant photographed. Any indented writings could be further examined by electrostatic detection equipment.

11.6. Examination with various light sources

Of particular benefit is examination under long-wave ultraviolet light.

- Note the image of the paper under UV.
- Note the paper luminescence, both colour and formation of the paper fibres.
- Note the luminescence of any inks on the paper, the inks may or may not be visible to the naked eye.
- Note the luminescence of any security features in the paper.
- Note the presence of any chemical watermarks, which often luminesce unlike genuine watermarks.
- Note any chemical staining on the paper, from chemicals and bleaches.
- Examine both sides of the paper as the fluorescence may differ.

Photograph if relevant.

Comparison may be made with a fluorescent scale (e.g. Ciba Geigy). Compare the paper fluorescence with the plastic cards and note the number of the card with which the paper corresponds the closest.

Other specialised lighting conditions may reveal something of use. Note the image of the paper under infrared luminescence using different filters, in particular any erased inks or chemical staining that can be enhanced by IR luminescence.

Photograph if relevant, noting incident wavelength.

Note the image of the paper under infrared radiation (absorption and reflection) at differing wavelengths. Note the behaviour of any marks and inks on the paper which may be absorbed at differing wavelengths.

Photograph if relevant, noting camera filter wavelength and type.

11.7. Comparison between two pieces of paper

To determine if a document is genuine or forged by comparison of the questioned document with an authentic security document or to determine if two pieces of paper may be from the same source.

Using the methods above, comparison can be done by the most useful methods:

- Visual examination (11.1)
- Micrometer examination (11.2)
- Microscopic examination (11.3)
- Examination under transmitted light (11.4)
- Examination under various light sources (11.6). Care must be taken that all papers are examined on the same background as the background influences the brightness of the luminescence. Therefore, always examine pages next to each other and not on top of each other.
- Comparison of guillotine marks. This may be done microscopically, preferably using a comparison microscope.

Note that when comparing two pieces of paper, the conditions under which the papers have been kept may affect their physical properties and appearance. Take into account any possible wetting, staining, bleaching, contamination by dirt, abrasion and wear or fading that one or both papers may have undergone.

A request may be made to determine whether or not two pieces of paper came from the same batch / ream / source. The above comparisons may be carried out, however, even if all the physical attributes of size, grammage, fluorescence and colour are similar, in the absence of any more identifying attribute (such as from the examinations in 11.8, 11.9, 11.10), any conclusion must be tempered by the fact that papers of identical appearance and composition are manufactured in vast quantities by modern manufacturing methods.

11.8. Determining the source of paper

The source of the manufacturer of the paper can be investigated by various methods:

- Comparison with other papers, sourced from shops, manufacturers or reference collections.
- Examination of watermarks. Comparison of the watermark with other watermarks from papers sourced from shops, manufacturers or reference collections. The watermark may be dated.
- Examination of any printed details on paper, which can be compared with papers sourced in shops, manufacturers or reference collections.

11.9. Physical fit of two pieces of paper

To determine whether or not torn, cut or shredded pieces of paper were once joined or were once part of the same document.

Examine all pieces of paper for obvious visible similarities which may allow pieces of paper to be grouped. Features to consider are as follows:

- Presence and style of handwriting.
- Presence and style of printing or typewriting.
- Colour of paper or inks on paper.
- Size and shape of fragments.
- Appearance of paper edges.
- Presence of watermarks, fibres or other security features.
- Folds.

Paper can be reconstructed on a flat surface, on low tack sheets or placed between clear glass or plastic.

Compare torn edges of pieces of paper. Features on the paper (ink lines, folds, watermarks) crossing from one piece of paper to another may help in the examination. To help in the comparison, the edges can be examined under the microscope. Electrostatic detection equipment can be useful in visualising torn edges. The examiner will then decide whether or not there is a physical fit between two pieces of paper depending on how closely the edges fit together. Consider the possibility of the physical properties of the paper having been altered due to wetting, creasing, contamination by dirt, etc.

Delaminated tears should be looked for. Delaminated tears occur when the tear is not perpendicular through the thickness of the paper – giving a pictorial appearance of two edges not fitting together. The electrostatic lift of both sides of the papers under examination is particularly useful when comparing delaminated tears.

Photographs and photocopies are methods of recording physical fits.

11.10. Determining if a piece of paper was part of a pad of papers

To identify similarities or differences to determine whether or not a piece of paper was part of a pad of paper.

Comparison of the papers should be carried out to determine whether or not the questioned paper is the same as the pad of papers. This should be carried out as 11.7.

If the paper has been torn from a notepad leaving a piece of torn paper behind in the notepad, treat the examination as a physical fit (11.9).

Examine the paper and the paper in the pad with electrostatic detection equipment in order to visualise indented writing on the paper or pad. The paper may have indented writing which can be sourced in the pad or vice versa.

Ink marks transferred (offset) from one page to another when the pages were previously together may provide a link. Marks may be revealed or enhanced by examination under UV or IR luminescence.

A similar approach can be taken when trying to determine whether or not a questioned piece of paper originated from a single piece of paper as opposed to a pad of papers. The papers may be of different types but may be linked by indented impressions or offsetting marks or stains.

11.11. Envelopes

Envelopes are commonly encountered in document examination and contain extra features not usually encountered when examining pages of paper. Examination should be carried out using the general paper examination and comparison listed.

Extra features of envelopes include:

- Shape of flap
- Orientation of flap
- Location of seam
- Gumming pattern
- Presence of window
- Printed features inside as well as outside
- Manufacturing information often inside the envelope
- Glues

Determine, compare and/or record any differences or similarities between the case envelopes themselves and between them and the specimens.

12. RECORDING AND INTERPRETATION OF RESULTS

Record all relevant details. Handwritten notes should incorporate all findings highlighted by visual, microscopic, transmitted and oblique light, ultra violet light examinations and under special lighting conditions. Photocopies of the paper can be useful to make notes on. Photographs or printed images of features such as indentations, luminescence and watermarks should be made.

For comparison of documents notes, photocopies, photographs and printed images should be used to record the appearance of both the questioned document and the authentic specimen document.

Along with notes, physical fits can be recorded by photocopies and photographs. Electrostatic lifts are also of particular use in visualising torn edges.

In determining whether or not a piece of paper originated from a pad of papers, comprehensive notes should be made along with relevant evidence in the form of electrostatic lifts or photographs/printed images of luminescent marks. Incident wavelengths should be recorded.

When comparing documents, interpretation should be made considering the occurrence of similarities and differences. Care should be taken in interpretation when considering the handling and storage of the document prior to examination. Fading, wetting, contamination, staining, etc. may have affected the properties of the paper. Interpretation as to whether or not a physical fit is present or whether a piece of paper originated from a pad of papers should also take into account possible distortion of the paper by wetting, staining, charring, etc.

Where the examination to be carried out is not specifically a paper examination, the document examiner may choose to make notes on the paper involved in the case, with reference to the principles above, but may choose not to make specific mention of the paper in his/her final report.

When the investigation requires an examination of the paper, then the examiner should report his/her findings giving relevant detail. Details of similarities and/or differences should be reported as well as the resulting interpretations that are based on them.

13. QUALITY ASSURANCE AND COMPETENCY

A competent examiner should be able to carry out all the procedures as stated and use the necessary equipment to obtain the best results.

A competent examiner should be able to carry out a full comparison between two or more documents and assess the significance of the similarities and differences between them.

All case reports should be fully checked by at least one other expert before being released to the investigator.

14. BIBLIOGRAPHY

- Biermann, C.J.; Handbook of Pulping and Papermaking, Academic Press, New York, 2nd Edition 1996
- Conners, T.E.; Banerjee, S.; Surface Analysis of Paper, CRC Press, New York, 1995
- Ellen, D.; The Scientific Examination of Documents – Methods and Techniques, Ellis Horwood, London, 1989 (2nd Edition 1997)
- Harrison, W.R.; Suspect Documents, Sweet and Maxwell, London 1956, 1966
- Hilton, O; Scientific Examination of Questioned Documents, Elsevier, New York, 1982
- Keim, K.; Das Papier, Otto Blersch Verlag Stuttgart, 1956

- Bodziak,W.J, Edge Characteristics of Commercially Produced Paper Stock, J-AM-SOC-QUEST-DOC-EXAM; 1998; V1 (1); P57-66

APPENDIX 11 – OVERVIEW PROCEDURE FOR NEAR INFRARED ABSORPTION AND REFLECTION EXAMINATION OF DOCUMENTS

1. INTRODUCTION

The absorption and reflection of incandescent visible light determines the colour of an object. The absorption and reflectance in the Near Infrared (NIR) region of the electromagnetic spectrum is however also very interesting to a document examiner due to the fact that substrates and inks may be differentiated in this region. Examination of the absorption/reflectance properties of documents (paper and inks) is one of the most common types of non-destructive examinations of documents.

2. SCOPE

This method deals with the examination of the absorption/reflection characteristics of documents as is commonly performed by a document examiner. The NIR region most commonly looked at is that ranging from the end of the visible region (about 700 nm) till 1100 nm (the limit of the sensitivity of a CCD camera).

Absorption/reflection examinations are commonly used for the examination and/or comparison of writing inks, mechanically or chemically erased entries, obliterated and added entries and of impressions on paper with an interfering background printing.

Examinations dealing with the absorption/reflection properties of inks and paper and the comparison thereof have quite a few limitations such as:

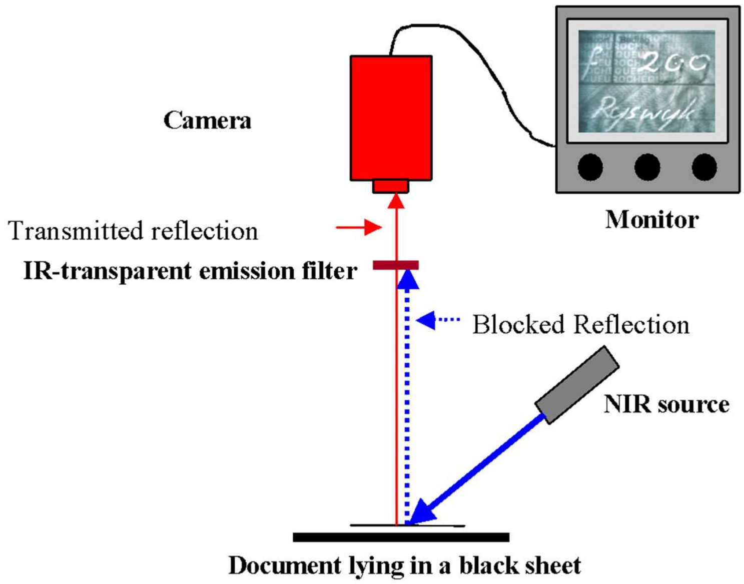
- The influence of the background (background printing or the surface underneath the page being examined);
- The influence of aging and exposure to light, chemicals and heat;
- The influence of the density of an inked entry.

Details on these influences will be discussed further on in this method.

3. PRINCIPLES

When a document is irradiated with radiation, certain wavelengths of this radiation are absorbed whilst others are reflected. The process of reflection does not involve a change in wavelength and may be specular or diffuse. The absorbed radiation (electromagnetic energy) is transferred to the atoms or molecules of the sample and converts the absorbing particles from their normal or ground state to an excited state. Normally on returning to the ground state (relaxation) the absorbed excitation energy is returned to heat. Alternatively, relaxation may occur partly as luminescence.

The sensitivity of the technique depends mainly on the quality and type of filters used and the quality and type of camera and lens applied. The sensitivity of most digital cameras diminishes quickly above 1000 nm and is cut off completely above 1100 nm. For examinations beyond 1100 nm a special camera is needed.



NIR absorption and reflection set-up

When examining inks on a document the absorption/reflection image is built up of the absorption/reflection of the substrate (usually paper) and that of the ink. The observable absorption/reflection of the ink therefore depends on the optical properties of the substrate and of the underlying surface. To assure that the underlying surface has a minimal effect on the results a black sheet of cardboard or plastic should be placed under the page to be examined to eliminate reflections from the underlying surface. Be aware not to compare inks that are on different types of paper.

One should be aware of the fact that with the set-up shown above, the examiner observes the sum of absorption/reflection intensity from ink and substrate. It should also be kept in mind that a less dense ink stroke absorbs less than a thicker (more intense) ink stroke of the same ink on the same paper.

Each wavelength of light has its own focal point. This means that whilst changing filters the image will become out of focus. A side effect of this phenomenon is that changing the camera focus may also change the appearance of the ink. Comparison of inks that have similar absorbing properties must therefore be done without changing the focal adjustment.

4. GLOSSARY

Absorption - Electromagnetic radiation (light) penetrating (absorbed) into a body of matter with no reflection or emission.

Band-pass filter - a filter that transmits a certain specified part of the electromagnetic spectrum. The filter is characterised by its nominal wavelength and its half-band width.

Excitation source - an object that produces light or other radiant flux.

Integration - a method to enhance detection by increasing the exposure time of the CCD or, where longer exposure times are not applicable, by means of digital image processing (adding or multiplying tool).

Long-pass filter - a cut-off filter that blocks radiation below and allows transmission of radiation above its cut-off wavelength. The cut-off wavelength is usually defined as the lowest wavelength at which the transmission first reaches 5% of the initial light-intensity.

Reflection - The reflection of light from the surface with no change in the wavelength; the reflection may be specular, diffuse (scattered) or mixed.

5. CROSS REFERENCES

- The application of luminescence to the examination of documents

6. PRESERVATION AND HANDLING OF ITEMS

Absorption/reflection examinations should be performed before chemically treating the document for fingerprints. Chemical treatment will influence the absorption/reflection properties of both inks and paper.

7. EQUIPMENT/INSTRUMENTATION/OPERATING CONDITIONS

- A visible light source (usually a tungsten lamp) without an infrared (heat) filter;
- A NIR-sensitive camera;
- Emission filters ranging from 600 to 1000 nm;
- A continuous band-pass filter ranging up to 1000 nm;
- A monitor;
- A printer.

The above equipment may be combined within one instrument (multispectral or hyperspectral analyser) or consist of separate components.

8. REAGENTS AND MATERIALS

A black sheet of cardboard paper or plastic to use as an underlying surface.

9. HEALTH AND SAFETY

This standard does not address the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

10. PREPARATION AND CALIBRATION OF EQUIPMENT AND MATERIALS

Check the manual of the equipment to see if a period of stabilisation is necessary.

11. PROCEDURE

Switch on the instrumentation.

Place the document (page to be examined) on a homogenous black sheet of cardboard or plastic. Do not examine one document on top of the other, as the absorption/reflection of the underlying document will influence the brightness of the image of the top document.

Select the appropriate excitation source (NIR).

Examine and compare the absorption/reflection properties of the inks by switching from one emission filter to another from a short wavelength to a longer wavelength.

If at a certain moment the image becomes too dark to distinguish features the light intensity may be increased and/or the integration time may be increased.

Be aware that the focus changes with each filter applied so that the image may become out of focus during filter changing.

Note any irregularities.

Record the viewed results.

12. RECORDING AND INTERPRETATION OF RESULTS

Print or store the image of the document for documentation or later retrieval. Also note or store the following parameters along with the image: the light source, the camera (emission) filter, the camera and the integration settings.

Note the interpretation of the evidence from the screen image, as this may be clearer than the printed image.

Consider if the differences in absorption/reflection of inks on a single document are caused by one of the following effects: a difference in ink composition, a difference in ink ageing or exposure of the ink to light or chemicals, a difference in line density (thickness), a difference in background, a difference in focus.

Do not make interpretations concerning ink comparison on different documents or if the inks on a single document are located on different (printed) backgrounds.

If it is necessary to report on the difference between inks and only slight differences in absorption/reflection are found or one of the other factors mentioned cannot be ruled out then the results must be verified using another method of comparison such as luminescence examination, spectroscopy (IR, Raman etc.) or preferably by chemical analysis (e.g. TLC, HPLC or CE).

If no differences in absorption/reflection are found then other, preferably chemical analysis, methods must be used before being able to draw a reasonably reliable conclusion on similarity.

13. QUALITY ASSURANCE AND COMPETENCY

A competent practitioner should be able to properly assess the possibilities and impossibilities of using absorption/reflection techniques for the examination of (inks on) documents. They must at all times be fully aware of the limitations of the method as stated in this procedure and must weigh their conclusions on the basis of these limitations. They must also be aware of other examination methods, which may overcome some of these limitations and therefore result in a more reliable conclusion.

A second examiner must always check conclusions based on interpretation of images of poor quality.

14. BIBLIOGRAPHY

- Brunelle, R.L.; Reed, R.W.; “Forensic Examination of Ink and Paper“; Charles C. Thomas – Publisher; Springfield, Illinois; 1984

APPENDIX 12 – OVERVIEW PROCEDURE FOR APPLICATION OF LUMINESCENCE TO THE EXAMINATION OF DOCUMENTS

1. INTRODUCTION

Luminescence is a compound name for two phenomena, fluorescence and phosphorescence. Both phenomena show the emission of radiant energy during a transition from an excited electronic state of an atom, molecule or ion to a lower electronic state. Examination of the luminescence properties of documents (paper and inks) is one of the most common types of non-destructive examinations of documents. Luminescence examinations on documents are performed in the visible and near-infrared parts of the electromagnetic spectrum after excitation of the subject by ultraviolet (UV) or visible (VIS) radiation.

2. SCOPE

This method will include all methods of optical luminescence examinations commonly performed by a document examiner. These methods apply excitation in the UV and VIS region resulting in emission in the VIS and (N)IR region.

Luminescence examinations are commonly used for the examination and/or comparison of paper, (security) printing inks, writing inks, mechanically or chemically erased entries, obliterated and added entries and certain types of impressions (such as on NCR-paper).

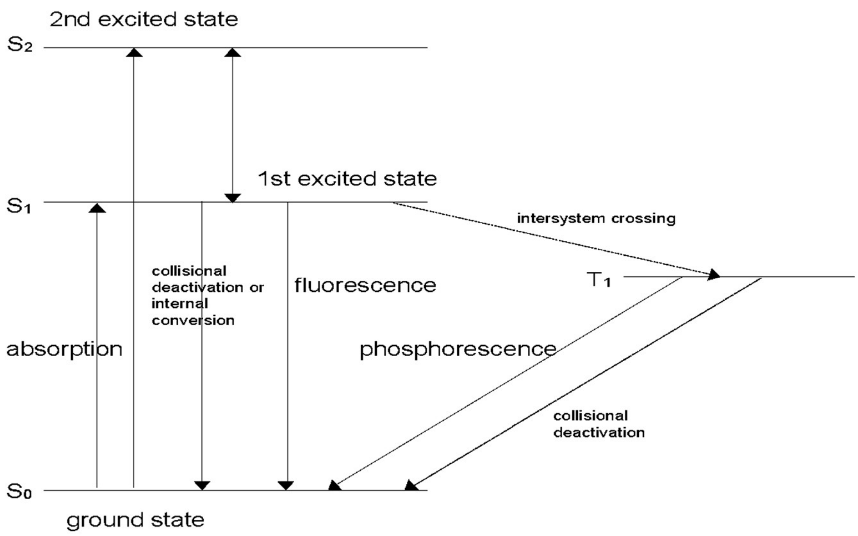
Examinations dealing with the luminescent properties of inks and paper and the comparison thereof have quite a few limitations such as:

- Different luminescent properties of both sides of a page;
- The influence of the background (background printing or the surface underneath the page being examined);
- The influence of ageing and exposure to light, chemicals and heat;
- The influence of the density of an inked entry.

Details on these influences will be discussed further on in this method.

3. PRINCIPLES

When a document is irradiated with (intense) UV or VIS light, electronic transitions may occur in molecules from paper and/or ink components. These transitions result in the molecule achieving an unstable excited state. To return from this excited state to its stable ground state a molecule needs to lose its excess energy. This energy may be transferred into heat or radiation. Generally, two forms of emitted radiation (luminescence) are recognised: in *fluorescence* the emitted radiation ceases immediately when the exciting radiation is extinguished, whilst in *phosphorescence* the emission may persist for longer periods (fractions of a second to hours).



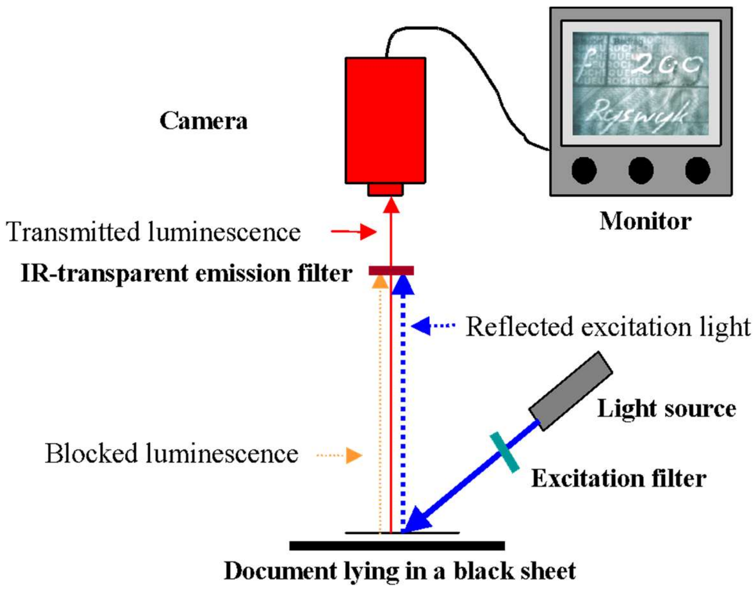
Energy scheme

The fact that luminescence normally only takes place after some of the excitation energy has been discarded in the form of heat implies that the energy of the luminescence is lower (at lower frequency or longer wavelength) than that of its excitation. Therefore a shift is always encountered in the direction of: UV to VIS to NIR. (λ_{ex} = UV ⇒ λ_{lum} = UV or VIS or IR and λ_{ex} = VIS ⇒ λ_{lum} = VIS or NIR)

Due to the fact that luminescence is a very weak phenomenon a filter must always be used to block the excitation light and prevent it from reaching the detector. Filters used for this may vary from the human eye (for UV-excitation) to long-pass and band-pass filters.

The sensitivity of the technique depends on the power of the excitation source (a strong tungsten-halogen, Xenon or laser source is usually preferred), the distance of the excitation source from the subject, the quality and type of filters used, the quality and type of camera and lens and the possibilities of the instrument (e.g. integration on chip or by software). The sensitivity of most digital cameras diminishes fast above 1000 nm and is cut off completely above 1100 nm. For examinations beyond 1100 nm a special camera is needed.

Depending on the type of luminescence examinations they should be carried out in the dark, preventing the disturbance of stray light as much as possible.



Luminescence set-up

When examining inks on a document the luminescence is built up of the luminescence of the substrate (usually paper) and that of the ink. The observable luminescence of the ink depends on the optical properties of the substrate and of the underlying surface. To assure that the underlying surface has a minimal effect on the results a black sheet of cardboard or plastic should be placed under the page to be examined to eliminate reflections from the underlying surface.

One should be aware of the fact that with the set-up shown above the examiner observes a mixture of radiation (luminescence) from the ink and the substrate. The examiner sees only a difference in luminescence intensity of ink and substrate. In other words: an ink which appears bright on a non- or weak-luminescing paper may, with the same filter combination appear dark on a strong luminescing paper! Be aware not to compare inks on different types of paper. It should also be kept in mind that a less dense ink stroke may luminesce earlier (at lower wavelength) than a thicker ink stroke of the same ink on the same paper!

Each wavelength of light has its own focal point. This means that whilst changing filters the image will become out of focus. A side effect of this phenomenon is that changing the camera focus near the initial point of luminescence of an ink may change the image from non-luminescent to luminescent. Comparison of inks that have similar luminescent properties must therefore be done without changing the focal adjustment.

5. GLOSSARY

Band-pass filter - a filter that transmits a certain specified part of the electromagnetic spectrum. The filter is characterised by its nominal wavelength and its half-band width.

Excitation source - an object that produces light or other radiant flux.

Fluorescence - a process by which radiant flux of certain wavelengths is absorbed and reradiated non-thermally at other, usually longer wavelengths.

Integration - a method to enhance detection by increasing the exposure time of the CCD or, where longer exposure times are not applicable, by means of digital image processing (adding or multiplying tool).

Long-pass filter - a cut-off filter that blocks radiation below and allows transmission of radiation above its cut-off wavelength. The cut-off wavelength is usually defined as the lowest wavelength at which the transmission first reaches 5% of the initial light-intensity.

Luminescence - the emission of radiant energy during a transition from an excited electronic state of an atom, molecule or ion to a lower electronic state.

Optical brightener - an inorganic or organic substance added to a paper product to enhance its whiteness. This enhancement is achieved by the absorption of ultraviolet radiation followed by the emission of light in the blue area of the visible spectrum.

Phosphorescence - similar to fluorescence, only with a longer duration. Transition takes place via a triplet state.

Short-pass filter - a cut-off filter that blocks radiation above and allow transmission of radiation below its cut-off wavelength. The cut-off wavelength is usually defined as the highest wavelength at which the transmission first reaches 5% of the initial light-intensity.

UV-dull - a substance is referred to as being UV-dull if it exhibits no visible fluorescence during excitation with ultraviolet radiation.

6. CROSS REFERENCES

- NIR Absorption and Reflection Examination of Documents

7. PRESERVATION AND HANDLING OF ITEMS

Luminescence examinations should be performed before chemically treating the document for fingerprints. Chemical treatment will influence the luminescent properties of both inks and paper.

Care should also be taken not to touch the documents without gloves in the area where luminescence examination is to be performed as this may also influence the luminescent properties of the inks and paper.

Prolonged exposure of inks and paper to strong lighting conditions as used for this type of examinations will change the properties of the inks (certain dyes) and the paper (e.g. optical brighteners and lignin) resulting in a kind of artificial ageing. This will make a reliable comparison at a later stage more difficult and less precise.

8. EQUIPMENT/INSTRUMENTATION/OPERATING CONDITIONS

- A UV light source of 365 and 254 nm
- A powerful visible light source (a Xenon lamp, a laser or a strong Halogen or tungsten lamp)
- Eye protection gear
- A VIS and NIR-sensitive camera
- Excitation filters ranging from 350 to 700 nm
- Emission filters ranging from 400 to 1000 nm
- A monitor
- A printer

The above equipment may be combined within one instrument (multispectral or hyperspectral analyser) or consist of separate components. Examinations must be performed in the dark necessitating a dark room and/or an instrument that may be closed off from stray light.

9. REAGENTS AND MATERIALS

A black sheet of cardboard paper or plastic to use as an underlying surface.

10. HEALTH AND SAFETY

Short-wave UV-light (254 nm) is extremely dangerous to the eyes and skin and may cause cancer. Avoid using a short-UV excitation source if possible, otherwise wear protective clothing and eyewear.

Protective eyewear must also be used when working with powerful light sources such as Lasers and Xenon lamps in an exposed environment.

This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

11. PREPARATION AND CALIBRATION OF EQUIPMENT AND MATERIALS

Check the manual of the equipment to see if a period of stabilisation is necessary.

12. PROCEDURE

After taking the necessary safety precautions switch on the instrumentation.

Darken the room if necessary to avoid as much stray light as possible.

Place the document (page to be examined) on a homogenous black sheet of cardboard or plastic. Do not examine one document on top of the other, as the luminescence/reflectance of the underlying document will influence the luminescent image of the top document.

Select the appropriate excitation source (UV or VIS).

Set the excitation band-pass filters to the appropriate region (start at a short wavelength and work your way up) and choose an appropriate emission filter (usually a long-pass filter at a longer wavelength than the excitation light) that blocks the excitation light but transmits radiation of longer wavelengths.

Examine and compare the luminescent properties of the paper (both sides) and/or the inks. If no luminescence is observed switch to a longer wavelength for the emission until all emission filters have been tried or luminescence has appeared. If still no luminescence is apparent raise the excitation wavelength by one filter and repeat the procedure in trying all emission filters. Repeat this procedure until all filter combinations have been tried.

If at a certain moment the image becomes too dark to distinguish features the light intensity may be increased and/or the integration time may be increased.

Be aware that the focus changes with the filter combination so that the image may become out of focus during filter changing.

Note any irregularities such as darker or lighter areas, differences in luminescence between both sides of the paper, luminescent watermarks (imitations) or other luminescent elements in the paper.

Record the viewed results.

13. RECORDING AND INTERPRETATION OF RESULTS

Print or store the image of the document for documentation or later retrieval. Also note or store the following parameters along with the image: the light source, the excitation filter, the emission filter, the camera and the integration settings.

Note the interpretation of the evidence from the screen image, as this may be clearer than the printed image. The fluorescent parts of the image may be highlighted on a photocopy of the document.

The interpretation of UV-excited-luminescence in the visible region is often better done by naked eye than by camera. However please keep in mind that there are serious health and safety issues involved in dealing with short wave UV, see 9.1

Consider if the differences in luminescence of inks on a single document are caused by one of the following effects: a difference in ink composition, a difference in ink ageing or exposure of the ink to light or chemicals, a difference in line density (thickness), a difference in background, a difference in focus.

Do not make interpretations concerning ink comparison on different documents or if the inks on a single document are located on different (printed) backgrounds.

If it is necessary to report on the difference between inks and only slight differences in luminescence are found or one of the other factors mentioned cannot be ruled out then the results must be verified using another method of comparison such as spectroscopy (IR, Raman etc.) or preferably by chemical analysis (e.g. TLC, HPLC or CE).

Due to the instability of optical brighteners in paper, conclusions of dissimilarity must not be drawn solely on the basis of slight differences in the UV-excited-luminescent properties of two documents. Other methods, preferably chemical analysis, must be used to confirm these differences.

If no differences in luminescence (ink or paper) are found then other, preferably chemical analysis, methods must be used before being able to draw a reasonably reliable conclusion on similarity.

14. QUALITY ASSURANCE AND COMPETENCY

A competent practitioner should be able to properly assess the possibilities and impossibilities of using luminescence techniques for the examination of (inks on) documents. They must at all times be fully aware of the limitations of the method as stated in this procedure and must weigh their conclusions on the basis of these limitations. They must also be aware of other examination methods that may overcome some of these limitations and therefore result in a more reliable conclusion.

A second examiner must always check conclusions based on interpretation of images of poor quality.

One must be aware of the fact that the power of the light source diminishes in time as does the sensitivity of the camera. These factors will influence the results that may be obtained using luminescence, as both are crucial to the detection of this weak phenomenon.

15. BIBLIOGRAPHY

- W.M. Riordan, "Detection of Nonvisible Writings by Infrared Luminescence and Ultraviolet Fluorescence", J-FORENSIC-SCI, 1991, V36(2), March, P466-469
- A.A. Cantu en R.S. Prough, "Some Spectral Observations of Infrared Luminescence", J-FORENSIC-SCI, 1988, V33(3), May, P638-647 (JFSCAS),
- J.A. Tappolet, "Comparative Examination of Ink Strokes on Paper with Infrared and Visible Luminescence", J-FORENSIC-SCI-SOC, 1986, V26(4), July, P293-299
- C.A. Sensi en A.A. Cantu, "Infrared Luminescence: Is it a valid method to differentiate among inks", J-FORENSIC-SCI, 1982, V27(1), Jan, P196-199
- P. Veillon, O. Rothenbuehler en J. Mathyer, "Some remarks on the optical examination of inks", INT. CRIMINAL POLICE REV, 1972, V27, P238-255

APPENDIX 13 – OVERVIEW PROCEDURE FOR INK ANALYSIS BY THIN LAYER CHROMATOGRAPHY

1. INTRODUCTION

The examination of inks on questioned documents may be performed for the following reasons:

to compare the inks on a document or

to identify the inks on a document (database of chromatograms is necessary).

After non-destructive optic methods have been applied exhaustively, a chemical analysis of the ink may give further information, e.g. the dye composition of the ink.

Thin layer chromatography (TLC) is a widely used, relatively cheap and simple but effective analytical method. TLC offers further a wide range of varieties depending on the range of solvents and stationary phases available.

2. SCOPE

This procedure will cover only the analysis of ink by TLC and the comparison of dye components. Because of the above mentioned varieties, only some exemplary conditions are described. It will not cover any post-chromatographical derivatization procedures.

The objective of this procedure is to provide methods to discriminate between inks of different questioned entries. TLC alone is generally not sufficient for definite identification of unknown inks. If a large number of inks has been analysed to build a library, TLC generally provides enough information to assign an unknown ink to a certain class of inks.

3. PRINCIPLES

Inks generally consist of dyes or pigments, binding agents and solvents. Only the dyeing substances can be seen without the aid of special lighting (ultraviolet or infrared light) or detection equipment (TLC-scanner). Some colourless substances may also be made visible after development of the TLC-plate through subsequent treatment with certain reagents (derivatization). In document examination generally, we do without determination of colourless substances, although some of these substances are easily visible with the aid of a UV-lamp or by means of luminescence in the far visible (orange/red) or infrared region.

In TLC a thin layer of a sorbent, usually silica gel, supported on a glass plate, plastic foil or an aluminium foil, serves as a so-called stationary phase. A solvent or solvent mixture serves as a so-called mobile phase. A small quantity of the mobile phase, about 5 mm high, is poured in a developing chamber. A TLC-plate with dried spots of ink extracts, about 10 mm distance from the bottom edge of the plate is brought into the mobile phase. Due to capillary forces the mobile phase moves upward and different substances (dyes) move different distances with the mobile phase (selective adsorption). As a result, a substance (dye) mixture is separated. For detailed descriptions of TLC in theory and in practice see references.

TLC can only separate substances that are soluble in the mobile phase. Pigments are often insoluble in common solvents and therefore inks containing pigments only, are generally unsuitable for TLC analysis.

Note: If ink contains pigment or pigments, it is not suitable for TLC. In this case it is necessary to use other techniques which do not require extracting ink from the paper. Optical methods or Raman spectroscopy are recommended.

4. GLOSSARY

Development chamber - Usually a glass tank with a cover to accommodate a TLC-plate in the proper dimension.

Extraction - Dissolving ink from paper or another substrate into a suitable extraction solvent.

Ink - Material, consisting of dyes, binding agents and solvents used to produce writing or images usually on paper.

Solvent system - Mixture of solvents suitable for the TLC separation of soluble substances.

TLC-plate - Glass plate, plastic foil or aluminium foil with a thin layer of adsorbent material (usually silica gel) used to perform thin layer chromatography.

HPTLC-plate - a High Performance TLC-plate, is a TLC-plate with finer adsorbent material resulting in a higher separation efficiency.

TLC-scanner - Spectrophotometer for scanning the spots on a TLC-plate, usually in reflectance and/or transmittance mode.

Chromatography - the separation of the components of a mixture by passing it over or through a substance that adsorbs selectively.

5. CROSS REFERENCES

- Application of Luminescence to the Examination of Documents
- NIR Absorption and Reflection Examination of Documents
- Toner examination
- The Examination of Inkjet Printed Documents

6. PRESERVATION AND HANDLING OF ITEMS

TLC analysis of inks should be performed before chemically treating documents for fingerprints. Chemical treatment may influence the chemical composition of the ink.

Documents should be stored in paper (not plastic) file folders, which are correctly labelled. Plastic folders may stick to the document and transfer materials, which can affect any future analysis of the ink.

Examination of the inks with powerful light sources or storage of the document in daylight will change the composition of the inks by photodecomposition of the dyes.

7. EQUIPMENT/INSTRUMENTATION/OPERATING CONDITIONS

There are a lot of different instrumentations on the market depending on different development techniques. Commonly used is the vertical development in a closed developing chamber, very often in a solvent saturated vapour phase. This paper can give only some examples of possible or commonly used instrumentation or techniques. In general, the following instrumentation can be used (list not exhaustive):

- A developing chamber preferably made of glass
- A scalpel or a micro punching device for taking ink samples from the document
- Lens or microscope
- A TLC-scanner (if available)
- Automatic extract applicator (if available)
- Ultrasonic bath or vortex (if available)

8. REAGENTS AND MATERIALS

- Micro tweezers
- Graduated cylinders and/or pipettes
- Micro-vials
- Capillary pipettes
- TLC- or HPTLC-plates Silica Gel (or Kieselgel) 60
- Appropriate solvents, e.g. water, methanol, ammonia, 2-propanol, acetone, dimethylformamide, tetrahydrofurane, pyridine.

9. HEALTH AND SAFETY

Because TLC utilises a variety of organic solvents, acids and bases it should be performed by skilled personnel, familiar with the handling of chemicals and the equipment of a chemical laboratory.

A laboratory environment should be used when working with organic solvents and other hazardous chemicals.

A lab-coat, solvent resistant gloves, safety goggles and a fume cabinet for handling volatile substances are appropriate when working with organic solvents, acids and bases.

This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determines the applicability of regulatory limitations prior to use.

10. PREPARATION AND CALIBRATION OF EQUIPMENT AND REAGENTS

It is recommended to wash the HPTLC- or TLC-plates prior to their use by placing them in a developing chamber and developing them with 2-propanol or methanol. After drying in an oven, the plates should be stored in dry atmosphere in a desiccator.
If new plates of good quality are available there is usually no need to wash them prior to use.

Solvent systems are produced by mixing measured volumes of the individual solvents. An appropriate quantity of the solvent mixture (about 5 mm high) is poured into the developing chamber. The developing chamber is closed for about 20 minutes to achieve equilibrium between liquid and vapour phase. It is recommended to prepare fresh solvent systems for every TLC-developing step. Solvent quality shall be at least analytical grade.

In general, a standard sample (dye mixture or well known ink) should be developed together with the samples in order to check the performance of the system. Chromatogram of standard sample must be very well known and repetitive.

11. PROCEDURE

11.1 Sampling

The sampling position should be examined carefully in order to avoid any interferences from background printing, dirt, fingerprints or other deposits. 5 to 10 mm ink line is punched or cut out and put into a micro-vial. A sample of blank paper of equal dimensions is taken for comparison.

The samples are extracted in 10 to 30 µl of an appropriate solvent for 15 minutes (table 1). Vortex or sonification in an ultrasonic bath for 30 seconds allows for quantitative extraction. (Note: Sonification may in some cases alter the composition of certain dyes by desmethylation).

Note: Whilst in solution the dyes should be protected from direct light as much as possible as dyes tend to photochemically decompose more rapidly in solution.

Small amounts (2 to 10 µl) of the extracts are spotted onto the TLC- or HPTLC-plate at a distance of about 10 mm from the bottom edge with the aid of a micro-pipette or an automatic applicator (lines). The spots should be as narrow (in vertical direction) as possible. The extraction solvent is allowed to evaporate, if necessary, with the aid of a cold air stream from a hair dryer (increased temperatures may cause degradation of dye components).

11.2. Development

The TLC- or HPTLC-plate is placed upright into the developing chamber, and the solvent system is allowed to migrate for about 6 cm. The plate is removed from the chamber and dried in a cold air stream or in an oven at moderate temperature, just high enough to evaporate the solvents (Note: If absorption spectroscopy is applied, the TLC-plate may not be heated. Spectra may be affected by desmethylation of some dye components).

Table 1: Exemplary extraction and TLC-conditions for certain inks

	Liquid ink	Ball point ink	Inkjet	Toner
Extraction	(1) dimethylformamide (2) 60% ethanol	(1) dimethylformamide/ water (4:1)[129] (2) methanol/acetone (1:1)[130] (3) pyridine	dimethylformamide/water (1:1)	(1) tetrahydrofurane
HPTLC- or TLC-plate	silica gel 60 with or without fluorescence indicator.	silica gel 60 with or without fluorescence indicator.	silica gel 60 with or without fluorescence indicator.	silica gel 60 with or without fluorescence indicator.
Solvent system	(1) 1-butanol, 2-propanol, water, glacial acetic acid (20:10:10:1) (2) 1-butanol, ethanol, water, glacial acetic acid (100:20:26:3) (3) 1-butanol, ethanol, water (2:1:1) (4) n-hexane, acetone, ethanol (20:5:1)	(1) 1-butanol, 2-propanol, water, glacial acetic acid (20:10:10:1) (2) ethyl acetate, ethanol, water (26:13:11) (3) 1-butanol, ethanol, water (50:10:15) (4) ethylmethylketone, 2-propanol, ammonia 25% (6:4:2) for black dyes	(1) 1-butanol, 2-propanol, water, glacial acetic acid (20:10:10:1) (2) 1-butanol, ethanol, water, glacial acetic acid (100:20:26:3) (3) 1-butanol, ethanol, water (4:3:3)	(1) 1-butanol, 2-propanol, water, glacial acetic acid (20:10:10:1) (2) 1-butanol, ethanol, water, glacial acetic acid (100:20:26:3)

11.3. Evaluation

129 Recommended for automating sampling

130 Recommended for hand sampling

The chromatograms are compared by the R_f–values and the colour of the spots. Significantly different R_f–values or colours indicate different dye components.

R_f–values can be calculated using the formula below:

$$R_f - \text{value} = \frac{\text{distance(start} - \text{spot)}}{\text{distance(start} - \text{solvent front)}}$$

A TLC-scanner may be used in addition to an evaluation of the TLC-plate by the naked eye, UV-, VIS-, and IR-luminescence. A TLC-scanner not only measures the R_f–values but provides the analyst also with spectra (generally in the UV/visible range) of the separated spots.

12. RECORDING AND INTERPRETATION OF RESULTS

The TLC-plate itself can be used as a storage medium, although it is recommended to take photographs of the plate soon after development because some dyes fade with time (Scanning the TLC-plate on a flat bed scanner is an alternative method for data storage). The TLC-plate is examined by UV-, VIS-, and IR-luminescence.

If a TLC-scanner is available, all operating conditions, positions and spectra of the separated spots should be recorded in a protocol and printed out.

If comparisons are made to chromatograms from a database, one should have in mind that TLC-results and especially the R_f–values depend on ambient temperature and humidity during the development. If a match in a database is found, it is necessary to analyse the unknown ink together with a sample of the ink from the database on the same TLC-plate.

The ink chromatogram has to be compared to the chromatogram of the paper blank in order to identify spots resulting from the paper.

In presence of significant differences in R_f–values and/or the colour of spots, the chromatograms and therefore the analysed inks contain different substances (dyes). Given the examined inks have not been stored under different light- or temperature-conditions, different chromatograms indicate different inks.

In the absence of any differences in ink chromatograms it is recommended to repeat the analysis with a second solvent system, preferably one that differs quite a bit from the first in types of solvents used. If after this still no difference is perceptible only the same dye composition has been proved, but it is still possible the inks came from different writing instruments or even different ink manufacturers.

13. QUALITY ASSURANCE AND COMPETENCY

Competent practitioners should be able to properly assess the possibilities and impossibilities of using TLC for the examination of ink. They must at all times be fully aware of the limitations of the method as stated in this procedure and must weigh their conclusions on the basis of these limitations. They must also be aware of other examination methods that may overcome some of these limitations and therefore result in a more reliable conclusion.

A standard sample (e.g. dye mixture) has to be analysed in parallel on each TLC-plate for quality assurance. The corresponding results have to be stored with the analysis data.

14. BIBLIOGRAPHY

- Stahl, E.; “Dünnschichtchromatographie”; Springer Verlag, Berlin, Heidelberg, New York; 1967
- Geiss, F.; “Fundamentals of Thin Layer Chromatography”; Dr. Alfred Hüthig Verlag; Heidelberg, Basel, New York; 1987
- Sherma, J., Fried, B. (editors); “Handbook of Thin-Layer Chromatography”; Marcel Dekker, New York, Basel, Hong Kong; 1991
- Brunelle, R.L.; Reed, R.W.; “Forensic Examination of Ink and Paper“; Charles C. Thomas – Publisher; Springfield, Illinois; 1984
- Wall, P.E.; “The Value of Planar Chromatography for the Analysis of Triphenylmethane Dyes”, Journal of Planar Chromatography, Vol. 6, 1993, pp. 394-403.
- Aginsky, V.N.; “A New Application of Instrumental Planar Chromatography in Forensic Analysis”, Journal of Planar Chromatography, Vol. 4, 1991, pp. 167-171.
- Aginsky, V.N.; “Comparative Examination of Inks by Using Instrumental Thin-Layer Chromatography and Microspectrophotometry”, Journal of Planar Chromatography, Vol. 38, No. 5, 1993, pp. 1111-1130.
- Aginsky, V.N.; “Forensic Examination of “Slightly Soluble” Ink Pigments Using Thin-Layer Chromatography”, Journal of Forensic Science, Vol. 38, No. 5, 1993, pp. 1131-1133,
- Differentiation of Ballpoint Pen Ink with TLC, EDEWG workshop materials, 2004, Bucharest, edited by Hofer R.

APPENDIX 14 – OVERVIEW PROCEDURE FOR INK ANALYSIS BY HIGH PERFORMANCE LIQUID CHROMATOGRAPHY

1. INTRODUCTION

High Performance Liquid Chromatography (HPLC) is a frequently used method for separation, quantification and identification of soluble substances.

In the field of questioned document examination, the method has a lot of applications: HPLC is for example used to estimate whether or not a document entry has been written with the same type of ink (e.g. ballpoint pen, or inkjet ink) or toner (e.g. charge control agents of photocopier or laser-jet toners) as the rest of the text. In some circumstances it is possible to estimate if an entry on a document has been written with the same ballpoint pen type and/or if it has been produced in the same period of time (relative age of entry). The investigation of soluble components from document material such as adhesives, plastics, solvents and/or optical brighteners can be used for checking the authenticity.

HPLC provides highly reproducible and reliable results. The HPLC method is very helpful for daily work as well as for research.

The advantages of this method are its high performance, the easy establishment of routine analyses and the reliability of the results.

2. SCOPE

This description is limited to theoretical basis and general applications of HPLC in questioned document examinations.

3. PRINCIPLES

In the physical point of view, HPLC is a further development of Thin Layer Chromatography (TLC); as it is also a separation method consisting of a liquid mobile phase and a stationary phase. The predominant advantage of HPLC is the increased evidence yield due to the identification of substances through the combination of retention time and absorption spectrum (for example).

A HPLC system includes in principle:

- injector
- pump system
- mobile phase
- stationary phase placed in a temperature controlled chamber
- detector(s)

- flow controller

An aliquot of the extract of a questioned document sample (e.g. ink from paper) is injected in the HPLC-apparatus by hand or by an auto-sampler/injector. A pump system brings the sample extract by the mobile phase - via capillary connections - on the start of a separation column (stationary phase), where the dissolved components are separated. After an individual, reproducible retention time (or run time) the different components leave the column, which is connected, to a detector. The detector provides the retention time and an additional parameter (such as the absorption spectra) simultaneously. It is vital, that the extraction is performed with a solvent that is compatible with the mobile phase. This prevents the formation of precipitates during the chromatography that can result in plugging capillaries or sticking of particles at the starting point of the column.

4. GLOSSARY

Pump system - There are two main types of pumps in the HPLC pump system: the low-pressure pumps which are responsible for mixing up to four different solvents (depending on the HPLC system; usually two different solvents are mixed), and the high-pressure pump which presses the solvent mixture through the capillary/column/detector system. The low-pressure pumps can be programmed in a way to change the solvent component ratios during a run cycle.

Injector - As mentioned above, the sample extract or a standard solution is injected by hand using a syringe or by an automatic injector. Depending on the HPLC-apparatus, the injection step is performed in a stopped-flow process or in a continuous flow.

Mobile phase - The mobile phase is a solvent or a solvent mixture. The mixture's ratio can be varied during a chromatography cycle (gradient). It is obvious that only solvents that are miscible to each other may be used for solvent mixtures. Buffer solutions are frequently used as one component. If a buffer is used it is important to check, that there is no precipitation of the salt(s) during the gradient (especially if a buffer/methanol or a buffer/acetonitrile mixture is used). The mobile phase pH must be within the intended range of the stationary phase.

Stationary phase - The stationary phase is basically a powder, which is densely packed, in a metal column. The particle size is in general 5 μm (for some purposes 3 or 3.5 μm is used). Particles themselves look like sponges with a pore size of 60 – 80 Å. Pore size of 125 – 500 Å is preferred if target molecules with a molecular weight more than about 4000 amu have to be separated. The stationary-phase material is either hydrophilic, bare silica (the so-called *Normal Phase*) or hydrophobic, chemically surface-modified silica (the so-called *Reversed Phase*). The hydrophobicity of the Reversed Phase is reached by surface silanization with alkyl silanes (C18, C8, C3), aryl silanes (phenyl), or functional alkyl silanes (CN). For some special purposes such as *Gel-Penetration*, *Gel-Filtration*, or *Ion-Exchange* a large variety of stationary phase material is available. For economical reasons, usually a short pre-column consisting of the same stationary phase material is placed in front of the expensive main-column for column protection.

Detector - Mostly a DAD (diode array detector) is used in HPLC systems. DAD detectors allow for permanent registration of absorption spectra during the chromatography and optimisation concerning recognition and quantification even after the chromatography run (e.g. plotting of the chromatogram at a different wavelength) as well as checking the purity of fractions. Special detectors such as refractive index detectors (RID), fluorescence detectors, mass spectrometry detectors (MSD) or a combination with Fourier-transformation infrared (FTIR) are commercially available.

Flow controller - To guarantee reproducible retention times it is essential to maintain a constant flow. This necessitates an adequate flow control system.

5. PRESERVATION AND HANDLING OF ITEMS

HPLC analyses of questioned document samples are destructive since only soluble components can be chromatographed and, as a consequence, have to be extracted from their support material. Therefore, handwriting analyses, for example, should be performed prior to HPLC analyses. Since chemical treatment may influence the chemical composition of substances of interest, document investigations for fingerprints should be performed after taking samples for HPLC.

If the printing of interest on a questioned document is produced by electrophotographic means, ESDA examination has to be carried out with extreme caution, to avoid contamination of the toner on the document by ESDA-toner particles. Otherwise, it is also possible to take samples from the document by carefully scrapping toner using a scalpel before ESDA without leaving additional latent impressions.

As a general rule, documents should be stored in the dark and not too close to a photocopy machine since environmental parameters such as light, temperature, ozone, etc. may extremely influence the degradation of ink.

6. EQUIPMENT/INSTRUMENTATION/OPERATING CONDITIONS

Detailed reference is to be made to conditions under which an examination should be carried out (i.e. humidity, temperature, lighting conditions, etc). There are a lot of different instruments on the market, which are almost all compatible to different commercial columns. The use of powerful software for data collection and treatment is of high importance for the research and development of new methods as well as for the routine analyses. For taking samples and subsequent treatment the following equipment can be used:

- Micro-tweezers
- Scalpel or micro-puncher

- Micro-pipette
- Small tubes with cap
- Micro-filters (these can be made by putting cotton wool into a micro-pipette plastic-tip and pressing it in the cone of the pipette tip)
- Glass or Teflon vials with Teflon-coated caps

Analytical conditions such as temperature, solvent mixture ratio, etc. should be as stable and reproducible as possible. Therefore, it is necessary to turn on the machine and to let it run for a while before use. In particular the temperature has to be taken into account, as the column must be at operating temperature. Degassing the solvents is important to get good chromatograms. Dissolved gas such as oxygen and nitrogen can be removed from the solvents by bubbling helium through a sintered frit submerged in the mobile-phase reservoir. Newer systems come with a built-in automatic ultrasonic degassing device.

7. HEALTH AND SAFETY

Alas, some of the frequently used solvents (e.g. methanol or acetonitrile) are hazardous to both the operator and the environment. Therefore, careful handling is recommended. A vacuum hood on top of the machine is advantageous, especially if helium bubbling is used for degassing.

8. REAGENTS AND MATERIAL

- Salts, acids and bases (for buffers) of highest purity.
- Ultra high quality (UHQ) water (especially recommended for UV spectra)
- Solvents of adequate purity (HPLC grade, UVASOL)

Some solvents should not be used for a too long period from the same reservoir (due to the formation of peroxides and/or degradation) and buffers should be exchanged frequently by fresh ones.

Pre-columns should be exchanged when pressure begins to rise drastically and columns should be exchanged when standard retention times and peak shape are unusual (out of ordinary limits).

9. PREPARATION AND CALIBRATION OF THE SYSTEM AND REAGENTS

Buffer’s pH should be checked. Data of production of buffers and any change and/or filling of solvents should be noted in the lab journal.

Prior to the injection of sample extracts of a questioned document, it is important to leave the apparatus in the run modus (such as: lamp on, detector on, solvent mixture, temperature, etc.)

for equilibration. A standard solution of similar or equal type as the compounds to be analysed as well as a solvent blank should be injected as first to check the retention time(s), peak shape and solvent blank peaks.

A blank should be measured after each sample to ensure that there is no entrainment from one sample to the next.

10. PROCEDURE

Only a general procedure for the analyses of writing material is described in this chapter.

Sampling and Extraction: The sampling should be executed in a way to avoid any additional traces such as latent impressions or fingerprints from the examiner. 5 to 10 mm ink line (ballpoint ink, typewriter ink, toner, etc.) are cut out with the aid of a clean scalpel or micro-puncher and put into a small tube. A paper sample of equal size is taken for comparison. The scalpel and/or the puncher have to be cleaned after each sample.

10 to 50 µl of the extraction solvent (preferably a component, which will be subsequently used as HPLC-solvent) are added to the samples. The tubes are vortexed and left for extraction if necessary. If a volatile extraction solvent is used, the tubes are capped for this purpose. The extract is then transferred into a micro-vial using a micro-pipette in such a way to avoid the simultaneous transfer of the ink-supporting substrate. If small particles are floating in the extract (often seen with toner extraction), a filtration step must be executed as described below.

In some cases, toner particles within the extract are as small that they pass through the filter. In these cases, it is suggested to centrifuge the extract and transfer the super-native via the filter into a clean vial.

If there is only a small amount of ink/toner on the questioned document (e.g. poor inking due to almost empty inkjet cartridge; defect or dried ballpoint pen) it may be necessary to take a larger sample. As a consequence, the amount of extraction solvent has to be adapted (e.g. 200 µl) The extraction is done as described under 11.2. The extract is filtered into a micro-vial and solvent volume is carefully reduced to 10 – 50 µl by slow evaporation of the solvent under a low nitrogen stream. To dissolve components that may adhere to the glass wall of the micro-vial above the current solvent level due to the evaporation step, the micro-vial is capped and vortexed before injection.

An aliquot of 5 – 10 µl is injected in the HPLC for analysis. A RP-C18 column with a DAD-detector for ink analyses and a RP-C18 or a normal phase size exclusion column with a refractive index detector for toner analysis are deemed to be appropriate.

11. EXAMPLES

Detail information for specific applications:

11.1. Reversed phase:

<u>Examination of toner products</u>

Extraction:	20 seconds extraction in an ultrasonic bath
Extraction liquid:	THF
Extraction volume:	40 µl
Injection volume:	10 µl
HPLC-eluent:	A: Water, HPLC grade
	B: THF, HPLC grade (e.g. Machery-Nagel, Chromoscan)
	Gradient: 60% B (t_0) □ 100% B (t_1 = 6 min) □ 100% B (t_2 = 10 min) □ 60% (t_3 = 20 min)
Column:	RP-18 (e.g. HP ODS Hypersil 5 µm, 100 x 4.6 mm)
Pre-column:	same as column
Flow:	0.5 ml/min
Temperature:	40°C
Detection wave length:	250 nm

<u>Examination of inkjet products</u>

Extraction:	20 seconds extraction in an ultrasonic bath
Extraction liquid:	dimethylformamide:water (1:1)
Extraction volume:	20 µl
Injection volume:	5 µl
HPLC-eluent:	A: $KClO_4$-Buffer pH 3.0 (10 mM $KClO_4$ [Fluka, MicroSelect] in water, adjust to pH 3.0 with $HClO_4$ [Merck, p.a.])
	B: Methanol (e.g. MN, SG Chromoscan)

Gradient: 30% B (t_0) □ 100% B (t_1 = 25 min) □ 30% B (t_2 = 30 min)

Column: RP-18 (e.g. MN, CC 150/4.6 Nucleosil 100-5 C 18)

Pre-column: same stationary phase as column

Flow: 1.0 ml/min

Temperature: 40°C

Detection wave length: 350 nm and 400 nm

Examination of ballpoint pen ink

Extraction: 20 seconds extraction in an ultrasonic bath

Extraction liquid: methanol:acetone (1:1)

Extraction volume: 20 µl

Injection volume: 5 µl

HPLC-eluent: A: $KClO_4$-Buffer pH 3.0 (10 mM $KClO_4$ [Fluka, MicroSelect] in water, adjust to pH 3.0 with $HClO_4$ [Merck, p.a.])

B: Methanol (e.g. MN, SG Chromoscan)

Gradient: 50% B (t_0) □ 100% B (t_1 = 20 min) □ 100% B (t_2 = 25 min) □ 50% B (t_3 = 30 min)

Column: RP-18 (e.g. MN, CC 150/4.6 Nucleosil 100-5 C 18)

Pre-column: same stationary phase as column

Flow: 1.0 ml/min

Temperature: 40°C

Detection wave length: 350 nm and 580 nm

11.2. Ion-pair reversed phase

The conditions mentioned below are suitable for the separation of basic, neutral and acidic dyes respectively in one run.

<u>Examination of ballpoint pen ink</u>

Extraction liquid:	HPLC-eluent
Extraction volume:	20 µl
Injection volume:	10 µl
HPLC-eluent:	A: 3,4 g/l TBAHS (Tetrabutylammoniumhydrogensulfate) and 1,6 g/l Citric acid-1-hydrate in Water B: Acetonitrile Ratio: 90% solvent A, 10% Solvent B
Column:	Alltima C18 (3µm) 7 x 53 mm
Pre-column:	phenomex security guard KJO-4282 (C 18)
Flow:	2 ml/min
Temperature:	40°C

12. RECORDING AND INTERPRETATION OF RESULTS

Firstly, any peak originating from the solvent and/or the supporting material (e.g. paper) should be marked as such by comparing the sample chromatogram with the paper blank run. To decide whether or not an entry on a questioned document has been made with the same ink as the rest of the document text, one can simply compare the corresponding chromatograms. In addition to the retention time the fractions (peaks) should also be compared with their absorption spectra (or mass spectra or FTIR spectra) to improve discrimination/identification.

For such interpretations it is necessary to establish a database (UV/VIS-absorption spectra, mass spectra, FTIR-spectra) of the most important dyes and their degradation products.

If two entries have been found to consist of the same components but in different ratios, one has to consider different possibilities of interpretation: Different types of ballpoint pens were used; the same ballpoint pen was used, but different storage (especially if the two entries are on different pages); the same ballpoint pen has been used, but the entries were produced on different times.

For quantification of components, the purity of the corresponding peaks have to be checked. This can be done by comparison of absorption spectra within each fraction (border and top of the peak).

13. QUALITY ASSURANCE AND COMPETENCY

Competent document examiners using this method should be able to properly assess the possibilities of using HPLC. They must at all times be fully aware of the limitations of the method and must weigh their conclusions on the basis of these limitations. They must also be aware of the examination methods that may overcome some of these limitations and therefore result in a more reliable conclusion.

14. BIBLIOGRAPHY

- Lyter, A.H., III, “Examination of Ball Pen Inks by High Pressure Liquid Chromatography”, Journal of Forensic Science, JFSCA, Vol. 27, No. 1, Jan. 1982, pp 154 – 160.
- Tebbett, I.R., Chen, C., Fitzgerald, M., and Olson, L., “The Use of HPLC with Multi-wavelength Detection for the Differentiation of Non Ball Pen Inks”, Journal of Forensic Science, JFSCA, Vol. 37, No. 4, July 1992, pp 1149 – 1157.
- Löfgren, A., Andrasko, B.S. and J., “HPLC Analysis of Printing Inks“, Journal of Forensic Science, JFSCA, Vol. 38, No. 5, September 1993, pp 1151 – 1160.

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