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LAW ENFORCEMENT STANDARDS PROGRAM

STANDARD REFERENCE COLLECTIONS OF FORENSIC SCIENCE MATERIALS: STATUS AND NEEDS

NILE & CJ
STANDARDS PROGRAM

U.S. DEPARTMENT OF JUSTICE
Law Enforcement Assistance Administration
National Institute of Law Enforcement and Criminal Justice

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prepared for the
National Institute of Law Enforcement and Criminal Justice
Law Enforcement Assistance Administration
U. S. Department of Justice

by

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FEBRUARY 1977

Points of view or opinions stated in this document are those of the author and do not necessarily represent the official position or policies of the U.S. Department of Justice.

U.S. DEPARTMENT OF JUSTICE
Law Enforcement Assistance Administration
National Institute of Law Enforcement and Criminal Justice

NATIONAL INSTITUTE OF LAW ENFORCEMENT AND CRIMINAL JUSTICE

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FOREWORD

Following a Congressional mandate[1] to develop new and improved techniques, systems, and equipment to strengthen law enforcement and criminal justice, the National Institute of Law Enforcement and Criminal Justice (NILECJ) has established the Law Enforcement Standards Laboratory (LESL) at the National Bureau of Standards. LESL's function is to conduct research that will assist law enforcement and criminal justice agencies in the selection and procurement of quality equipment.

In response to priorities established by NILECJ, LESL is (1) subjecting existing equipment to laboratory testing and evaluation and (2) conducting research leading to the development of several series of documents, including national voluntary equipment standards, user guidelines, state-of-the-art surveys and other reports.

This document, LESP–RPT–0601.00, "Standard Reference Collections of Forensic Science Materials: Status and Needs," is a report developed by LESL and approved and issued by NILECJ. Additional reports as well as other documents are being issued under the LESL program in the areas of protective equipment, communications equipment, security systems, weapons, emergency equipment, investigative aids, vehicles and clothing.

Technical comments and suggestions concerning the subject matter of this report are invited from all interested parties. Comments should be addressed to the Program Manager for Standards, National Institute of Law Enforcement and Criminal Justice, Law Enforcement Assistance Administration, U.S. Department of Justice, Washington, D. C. 20531.

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[1]Section 402(b) of the Omnibus Crime Control and Safe Streets Act of 1968, as amended.

GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AA	—Atomic Absorption
AAFS	—American Academy of Forensic Scientists
AATCC	—American Association of Textile Chemists & Colorists
ABFLO	—Association of Bedding and Furniture Law Officials
ADH	—Alcohol Dehydrogenase
APA	—American Pharmaceutical Association
ASQDE	—American Society of Questioned Document Examiners
ASTM	—American Society for Testing and Materials
ATF	—Alcohol, Tobacco and Firearms (Bureau)
BA	—Blood Alcohol
CRE	—Central Research Establishment (Crime Lab), Aldermaston, U.K.
DCRT/CIS	—Division of Computer Research and Technology/ Chemical Identification System
DEA	—Drug Enforcement Administration
DET	—Diethyltryptamine (a Hallucinogenic Drug)
DMS	—Documentation of Molecular Spectroscopy
DOT	—Department of Transportation
DSC	—Differential Scanning Colorimeter
DTA	—Differential Thermal Analysis
FBI	—Federal Bureau of Investigation
FDA	—Food and Drug Administration
FPL	—Forest Products Laboratory (Dept. of Agriculture)
FSM	—Forensic Science Material
GC	—Gas Chromatography
GC–EC	—Gas Chromatography (using an) Electron Capture (Detector)
GC–FI	—Gas Chromatography (using a) Flame Ionization (Detector)
GC–MS	—Gas Chromatography (followed by) Mass Spectrometry
GLC	—Gas-Liquid Chromatography
IBM	—International Business Machines Co., Inc.
IR	—Infrared
IRDC	—Infrared Data Committee (of Japan)
ISCC	—Inter-Society Color Council
JPL	—Jet Propulsion Laboratory
LEAA	—Law Enforcement Assistance Administration
LESL	—Law Enforcement Standards Laboratory
LSD	—Lysergic Acid Diethylamide (a Hallucinogenic Drug)
MP	—Melting Point
MS	—Mass Spectrometry
NAA	—Nuclear Activation Analysis
NAD	—Nicotinamide Adenine Dinucleotide (also written DPN)
NBS	—National Bureau of Standards
NCDC	—National Center for Disease Control
NIH	—National Institutes of Health
NMR	—Nuclear Magnetic Resonance
NPC	—National Pharmaceutical Council
NSF	—National Science Foundation

OTC	—Over-The-Counter (Drugs)
PD	—Police Department
PDR	—Physicians Desk Reference
P–GC	—Pyrolysis (followed by) Gas Chromatography
PMA	—Pharmaceutical Manufacturers Association
P–MS	—Pyrolysis (followed by) Mass Spectrometry
PPG	—Pittsburgh Plate Glass Co., Inc.
QDE	—Questioned Document Examiner
RI	—Refractive Index
SEM	—Scanning Electron Microscope
SRC	—Standard Reference Collection
SRM	—Standard Reference Material
THC	—Tetrahydrocannabinol
TLC	—Thin Layer Chromatography
USP	—United States Pharmacopeia
USPC	—United States Pharmacopeial Convention
USPS	—United States Postal Service
UV	—Ultraviolet
VA	—Veterans Administration
XRD	—X-Ray Diffraction

STANDARD REFERENCE COLLECTIONS OF FORENSIC SCIENCE MATERIALS: STATUS AND NEEDS

1. INTRODUCTION

This report provides an overview of the state of the art of forensic science materials (FSMs). It addresses the needs, uses, and forms of standard reference collections (SRCs) for a select group of FMSs. Where existing SRCs do not satisfy the need, potential SRCs, SRC forms and related questions are discussed in some detail.

This report is based on a fairly broad coverage of the entire FSM field, done over a relatively short time. It therefore does not purport to recommend definitive courses of action. Rather, the recommendations presented are intended to give direction and stimulus for further investigations into certain areas and to indicate those areas where no action appears warranted at present.

Specifically, the following tasks were undertaken during the course of this study:

a) Development of a comprehensive, but not exhaustive, data base. This was accomplished through a survey of criminalists, educators, scientists, and manufacturers, as well as by a review of the literature.

b) Location of the major existent FMS collections, particularly those relevant to the needs of crime laboratories, and the examination of their characteristics, availability and suitability.

c) Development of a list of FSM classes, ordered according to the degree they are needed by crime laboratories. These needs relate to improvement of operating efficiency, augmentation of analysis reliability and accuracy, and extension of analysis capabilities. The ranking reflects both the opinions of those persons surveyed and the author's analysis of all relevant factors.

d) Examination of alternatives to the establishment of new collections and to the maintenance of existing collections.

e) Formulation of recommendations as to the size, scope, and content of proposed collections.

f) Formulation of recommendations regarding restrictions on user access to SRCs.

g) Formulation of recommendations as to research required for SRC development.

h) Making of recommendations for candidate developers from among those individuals and agencies having the experience, expertise, resources and willingness to develop proposed SRCs—or at least to further explore SRC development feasibility and viability.

i) Estimation, where possible, of the costs of preparing the proposed SRCs. Purchase or accessing fees were also estimated in some instances.

2. POTENTIAL FORMS AND USES OF STANDARD REFERENCE COLLECTIONS

An SRC can assume many different forms. Some of these forms and their associated variants are:

SRC Form	*Variants*
a. Physical Specimens	Loose or mounted.
b. Photomicrographs	Filters: light wavelength; phase contrast; polarizing; petrographic; transverse, longitudinal and whole specimens; strains; magnification; dark field, etc.
c. Spectra	Physical property measured; range of the dependent variable; nature of scales (linear, log, etc.); condition of sample; and instrumental settings and resolution.

d. Characterization Data	Melting point (MP); crystalline shape; color; solubility; refractive index (RI); density; morphology; color test reactions; etc.
e. Manufacturing Data	Names and addresses of manufacturers; makes and model names/numbers; dates of production; serial number ranges; composition; standard deviations of identifying, measurable characteristics; distribution numbers and paths; etc.
f. Identification Markings	Markings that would permit a criminalist to classify in an item of evidential value, or to individualize it. Examples of the former are laundry markings and paper watermarks. An example of the latter is jewelry markings. Rifling marks can be used to both classify and individualize weapons.

The uses of such reference collections are manifold:

a) "Classification." Often the delimiting of a substance, submitted to a crime laboratory for analysis, to a specific subclass (within the general material class) is of great use in suspect development or elimination. Thus, the identification of the make and model of a vehicle from the analysis of a paint chip found at the scene of a hit-and-run accident would be of considerable value in limiting the search for the suspect vehicle. "Classification" here could have resulted from the search of a reference collection, consisting of reproductions of standard vehicle colors. Vehicle classification (make and model) occurs when a color match with the paint chip is obtained. "Classification" analyses invariably draw on such reference collections and data files (though frequently, through experience, the data resides in the criminalist's memory). "Classification" type analyses are also of use in courts of law.

b) "Individualization" is accomplished when the unique identity of evidential material is determined. Individualization of the paint chip of the previous example could result from a fitting of the chip into a scrape mark on a suspect car. "Individualization" typically results from a "jigsaw puzzle" type of match and as such does not require the use of an SRC. Other typical "individualization" analyses occur with tool marks, rifling, shoeprints, fingerprints, etc. Such analyses can carry substantial weight in court, but generally require prior suspect development.

Many types of analyses contain the elements of both "individualization" and "identification." For example, consider an IR spectrum taken on a confiscated drug. By comparison of the spectrum with an SRC of known, standard drug spectra, the generic class of the drug can be determined. Furthermore, a comparison of the "unknown" spectrum with that of a confiscated sample from another source could provide proof of their similar origin. That is, an extremely good match of spectra could result in an "individualization."

Frequently, the prosecution or defense at a trial will claim "similarity" or dissimilarity" (in either appearance, or physico-chemical behavior) between evidential material from a crime scene and that related to the defendant. The opposing attorneys may try to have the evidence suppressed, or to minimize its impact, by demanding the identity of the material, where such information was not presented. Thus, it is not sufficient to claim that two pieces of evidential material (e.g., fibers, glass fragments, bullets) are "similar" or "dissimilar"; the material should also be classified if the evidence is to carry maximum weight in court.

c) A third class of uses of SRCs is in instrument and/or baseline calibration. Thus glass standards can be used to calibrate a device used to determine refractive index and/or dispersion. A chemical standard can be used to quantify a procedure or result.

Into this class should also be placed reference materials such as liquid specific gravity standards used in the determination of the density of, say, glass fragments. Typed blood standards run concomitantly with evidential blood samples to check on the validity of blood group tests also fall within this class. Spectra of "standards" of known composition can be used to quantify spectra of "unknowns."

d) A fourth use of SRCs is in the interpretation of test results, such as the use of "population statistics'' to estimate the probability of a conclusion based on a laboratory analysis. An example is the use of blood statistics in paternity cases.

e) Standard Reference Materials are extremely useful in research projects aimed at developing or improving methodologies and/or equipment.

f) SRCs are frequently of great use as training or instructional aids.

g) SRCs also tend to speed up analysis. One motto of forensic scientists is ''the older the clue—the colder the trail.'' Therefore, the quicker a clue is analyzed the greater its utility.

There are undoubtedly many other valid uses for standard reference materials and/or data files.

3. METHODOLOGY FOR CONDUCTING THIS STUDY

First, the forensic science literature was scanned, and information regarding those materials which criminalists classify as being of an evidential nature was obtained (See appendices C and D). Then, a group of criminalists was contacted and queried as to which materials could conceivably be of evidential value. From this, a list of 62 FSM classes (table 1) was produced and presented to a second group of criminalists for their selection of those classes that would satisfy basic laboratory needs. From these interviews, a final list of 34 FSM classes was obtained and is given in table 2. These 34 classes were then ranked according to their relative importance and the accessibility of data. Preliminary conclusions were formed as to which SRCs should be recommended for development or further consideration. In addition to the needs expressed by the criminalists contacted, the factors which influenced these recommendations included the availability of existing reference collections that could at least partially fill these needs, a mathematical analysis (see appendix G), and a certain amount of subjectivity.

4. FINDINGS

This section describes the status (as of Nov. 1974) and recommendations for each of the 34 FSM classes listed in table 2. A list of these classes, grouped according to recommendation, is presented in table 3.

Each FSM is discussed below in a separate subsection labeled 4.x, where the x is the FSM class number as given in table 2. Each discussion contains a ''background'' section (denoted as 4.x.1). If positive recommendations resulted from an analysis of the factors brought out in the background discussion, these are given in 4.x.2 and are then amplified in five subsections as follows:

Table 1. The Initial List of FSM Classes Having SRC Potential

FSM CLASS OR FORM	FSM CLASS OR FORM
1. Poisons	13. Blood, Human
2. Drugs, Abused	14. Blood, Animal
3. Drugs, Toxic	15. Body Fluids, Human
4. Pill Ballistics	16. Prints (Finger-, Palm-, etc.)
5. Tobacco Products	17. Wound Ballistics
6. Alcohol, —ie Beverages	18. Paper, Writing
7. Lipsticks	19. Watermarks, Paper
8. Hair Cream, Grease, Spray	20. Pens, Markers, Inks
9. Perfume	21. Pencils, Crayons
10. Cosmetics, Other	22. Typefaces, Typewriters
11. Hair, Human	23. Typewriter Ribbons
12. Hair, Animal	24. Transfer Letters, Dry

25. Voiceprints
26. Glues, Adhesives
27. Tape (Black, Scotch, etc.)
28. String, Rope
29. Knots
30. Wood (Species) Bark
31. Soils
32. Wire, Cable
33. Nails, Screws, Bolts
34. Glass, Auto
35. Glass, Non-Auto
36. Leather, Shoe
37. Shoe-, Sneaker-Prints
38. Plastics, Synthetic Fibers, Cloths
39. Natural Fibers, Cloths
40. Laundry Marks (Visible/Invisible), Dyes
41. Tire Tread Patterns
42. Tire Tread Composition
43. Auto Silhouette Patterns
44. Paint, Auto
45. Paint, Non-Auto
46. Road Construction Materials
47. Ammunition
48. Explosives
49. Weapons, Firearms
50. Bullet Ballistics
51. Fire Accelerants
52. Safe Construction Materials
53. Known Criminal Data
54. Stolen Cars, Boats, Bikes
55. Missing Credit Cards
56. Missing Securities
57. Missing Persons
58. Fraudulent Check, Handwriting
59. Missing Valuables/Markings
60. Pipe, Tubing
61. Shoe Polish
62. Jewelry Markings

Table 2

FSM Classes for Further Consideration

1	Drugs (abused, toxicological)
2	Solid Dosage Drugs
3	Tobacco
4	Alcohol
5	Cosmetics
6	Hair, Human
7	Hair, Animal (and feathers)
8	Blood, Human
9	Blood, Animal
10	Body Fluids, Human, Animal (excluding blood)
11	Prints (finger, palm, etc.)
12	Voice Prints
13	Paper, Writing
14	Paper, Watermarks
15	Typewriters, Typewriting, Ribbons
16	Inks, Pens, Markers
17	Dyes, Stains, Pigments
18	Fibers, Synthetic
19	Fibers, Plant
20	Woods, Barks
21	Adhesives
22	Soils
23	Glass, General
24	Glass, Auto (and plastic lenses)
25	Paints, General
26	Paints, Auto
27	Shoe, Sneaker Prints
28	Tire Tread Patterns
29	Tire Tread Composition
30	Safe Construction Materials
31	Explosives
32	Firearms, Weapons
33	Ammunition, Residues
34	Accelerants

Table 3
SRC Recommendations

FSM CLASS	SRC DESCRIPTION
Recommended for Development or Further Consideration	
Tire Tread Illustrations	Flat Representations
Solid Dosage Drugs	Pill Identification File
Glass, Auto Headlight	Sealed Beam RI & Density Population Statistics
Firearms	Rifling Marks/Manufacturing Data Card File
Blood, Human	Population Statistics
Alcohol	Physical Standards in H_2O
Paints, Auto	Color Coded Card File
Drugs	Physical Standards
Typewriting	Exemplars, Museum
Fibers, Synthetic	Specimens, Physical & Manufacturing Data
Prints, Finger	Analyze Methodology
Explosives	Specimens, Physical & Manufacturing Data
Hair, Animal & Feathers	Specimens & Atlas
Fibers, Plant	Specimens, Photomicrographs
Not Recommended for Consideration at this time	
Accelerants	Specimens, Physical & Manufacturing Data
Ammunition	Specimens or Photos and Physical & Manufacturing Data
Blood, Animal*	Specimens (for antisera testing)
Cosmetics*	Specimens; Physical & Manufacturing Data
Dyes, Stains	Physical Data
Explosives	Specimens, Photomicrographs
Glass, General	RI & Density Population Statistics, Physical & Manufacturing Data
Hair, Human	Representative Samples, Photomicrographs
Inks, Writing	Physical & Manufacturing Data and TLC Color Slides
Paints, General	Physical & Manufacturing Data
Paper, Writing	Physical & Manufacturing Data, Specimens
Shoe Prints	Representations, Manufacturing Data
Tire Tread Composition	Physical & Manufacturing Data
Watermarks, Paper	Specimens, Manufacturing Data
Woods, Bark	Specimens, Photomicrographs (Pyrograms?)
Indeterminate (Due to inadequate data base)	
Adhesives	Physical, Manufacturing Data
Body Fluids	Photomicrographs of animal semina
Prints, Voice	Criminal Specimen File
Safe Insulation	Physical, Manufacturing Data, Photomicrographs
Tobacco	Paper, Filter Specimens

*Although the data base for this FSM was inadequate for a positive recommendation, it was sufficient for a "not recommended" classification.

SUBSECTION TITLE	SUBSECTION CONTENTS
Basic SRC Specifications	Recommended SRC form including: number and description of its elements; scope; and associated characterizing, manufacturing and instrumental data.
SRC Sources	Potential sources of the SRC elements.
Implementation Factors	Potential SRC custodians, distributors; methods of dissemination and/or accessing of the SRC; purchasing and/or accessing costs/fees; SRC development cost and time requirement estimates.
User Factors	Suggested users; user requirements and restrictions.
Research Requirements	Research required prior to SRC development; associated cataloging procedures, and search-and-identify methodology required for effective SRC utilization.

4.1 Drugs (Abused, Controlled, and Toxic)

4.1.1 Background

One of the primary stimuli to the growth in the number and size of crime laboratories over the past five years has been the increasing drug abuse problem. Drug analyses account for over 60 percent of almost every crime laboratory case load. As evidential material, drugs are associated with many variables, among these being:

a) The substance may be obtained from a drug raid, a homicide, a suspected drug overdose, or elsewhere;

b) The substance may have come from a labeled container, a night table, an unmarked envelope, a pocket, a patient, a survey, or a corpse;

c) Seized substances can occur in liquid, powder, tablet, capsule or ampoule forms;

d) Seized substances can be commercially manufactured, home-made, or a combination of the two;

e) The substance to be analyzed can, in fact, contain: abused or controlled narcotics, or metabolites thereof; toxic or dangerous substances; or it may be totally innocuous.

f) Whatever the active components of the questioned substance may be (if any), it is almost certain to also contain: excipient material; non-active fillers; binders; coloring agents; coating materials; or ''cutting'' agents. Intermediate compounds may also be present at detectable levels, especially if the substance is clandestinely synthesized. Material submitted for analysis may be a body fluid (e.g., blood, urine), or an extract from a cadaver organ. In such cases, analysis is further complicated by the presence of other indigenous substances.

If a drug overdose or poisoning is suspected, the analyst will attempt to determine the nature and amounts of the possible causative agents. The survival of a patient may depend on the speed and correctness of this analysis. Alternatively, the solution and/or courtroom presentation of a homicide case may rest upon the analyst's findings. ''Screening'' of body fluids typically involves detecting the presence of narcotics or their metabolities. If the analysis is for use in a court of law, the analyst is generally required to identify and quantify all controlled (illegal) substances present. The nature of any and all ''cutting'' agents, fillers, etc., should also be determined.

Because drug analysis is so complex, the analyst often depends on associated factors, such as the appearance of a specimen, to speed and direct his efforts. In this regard, pill identification (commonly termed ''pillistics'' or ''pill ballistics'') is a valuable tool of the drug analyst, and is discussed in section 4.2.

Methods of drug analysis have not been standardized and remain in a state of flux. Nevertheless, there do appear to be many excellent lab manuals and sources of analytical techniques. An extensive bibliography of articles dealing with drug analysis is found in [BI–2]*. Informatics, Inc. has developed a computerized information service—Toxicon— containing citations and abstracts of over 200,000 articles containing toxicological information.

The American Academy of Forensic Scientists (AAFS), Association of Official Analytical Chemists (AOAC), Drug Enforcement Administration (DEA), National Center for Disease Control (NCDC), Veterans Administration (VA), and others are active in the development, perfection and codification of drug analysis methods.

Many laboratories have developed extensive data files related to drugs. Among the more notable files are:

a) NIH's computerized GC–MS data base and search identification system (DCRT/CIS).

b) The Finnigan Corporation (Sunnyvale, California) markets a GC–MS unit with a built-in memory of the peak locations for 133 drugs of abuse.

c) The Sadtler, ASTM, Coblentz, AOAC, IRDC (Japan) and DMS (Germany) files all contain spectrophotometric data elements which pertain to abused drugs. Sadtler markets the following spectra collections:

Type	*Compounds*	*Number*	*Cost*
IR	Abused Drugs	600	$500
UV	Abused Drugs	300	250

IR, Prism	Pharmaceuticals	1000	365
IR, Grating	Pharmaceuticals	300	128
UV	Pharmaceuticals	1500	525

d) New York City has a 500 to 600 element physical specimen drug SRC. Most other crime laboratories also have modest drug collections. The sources of these drugs are invariably multiple and the drugs themselves are of questionable purity and concentration.

e) U.S. Customs has spectral data (>900 spectra) and physical constants for alkaloids. These data, being developed in Czechoslovakia, are updated periodically.

*Symbols in brackets refer to entries in Appendix H—References.

f) The U.S. Pharmacopeia (USP), issued annually by the USPC, gives general test procedures for many substances, including toxicological ones.

Methods of analysis for "controlled substances" vary with: the aims of the tests performed (i.e., screening, identification or confirmation, quantification, etc.); the class of the drug (i.e., amphetamine, barbiturate, morphine derivative, hallucinogen, etc.); and the nature of the sample matrix. Drug analysis techniques frequently encountered include: spot tests; microcrystal tests; spectral methods such as UV, IR and fluorimetry; thin layer-, gas-, paper-, and gas liquid-chromatography; mass spectrometry (often preceded by a chemical or chromatographic separation); and XRD.

Most laboratories require positive results from at least two test procedures before a drug is considered to be identified. Many courts of law also require quantification of controlled constituents. Identification and quantification of cutting agents and other non-active constituents add weight to drug identification analyses.

In order to do accurate identification and quantification of controlled substances, it is necessary to have standards of these materials.

An SRC consisting of pure specimens of every controlled substance on Controlled Substance Schedules I through V [EV–1] is seen by many crime labs to be needed. These standards would be used:

a) As a control, along with an unknown substance, when using TLC, GC, or GLC identification techniques. Used thusly, a standard of known purity often permits quantification along with identification of the unknown.

b) To confirm the efficacy of reagents used with spot and microcrystal tests.

c) For training purposes and to develop internal sets of standard spectra or characterization data, which, in turn, can also serve as SRCs. Spectra SRCs are especially useful for spectrometric analyses where the independent variable (wavelength) is an absolute, reproducible quantity.

Common "cutting agents" and impurities should also be included in this SRC. Presently, only those agencies registered with the Drug Enforcement Administration (DEA) may obtain controlled drugs. Typical drug sources include the drug manufacturers, USP, DEA and confiscated drugs. It is anticipated that USP's role as a source of pure "controlled substances" will increase, and DEA's role may decrease. Most Schedule II through V drugs are presently available from legitimate sources. Several Schedule I drugs which, unfortunately, rank among the more commonly abused drugs, are not obtainable in a known-purity state; these include LSD, DET, and THC.[1] Heroin is not available in the "free-base" form preferred by some analysts.

Among the more common complaints heard from criminalists regarding drugs are: the diversity of drug sources; the exorbitant cost of drug "standards"; and the scarcity of drug standards of certified purity.

The following is quoted from the February 1973 issue of *Microgram:*

> "Today, there is a recognized need for a central source to maintain authentic samples of narcotics and other drugs of abuse for legitimate use by analytical, clinical and police laboratories, researchers and toxicologists. The United States Pharmacopeial Convention, Inc., was urged by the Bureau of Narcotics and Dangerous Drugs, the Food and Drug Administration, and the National Institute of Mental Health to undertake this important task."

[1] USP has a supply of Delta-9 THC and LSD samples.

"The USPC is now providing this service and is launching a new program that involves the testing and distribution of samples of Schedules I and II drugs, known as "Authentic Substances." Each batch of an authentic substance will have been evaluated by at least two laboratories and found suitable for qualitative and semi-quantitative purposes."

Two performance standards for "Narcotic Field Test Kits" are being developed for LEAA by the NBS Law Enforcement Standards Laboratory. One of these addresses the spot-test type of kit, and the other the thin layer chromatography type.

The Lederle Laboratories have developed a "Urine Toxicological Control" and a "Serum Toxicological Control." These "controls" are in the form of bottles whose contents, when mixed with water, closely approximate natural urine or blood, each containing a number of known drugs of abuse. The drug standards being developed by the NCDC are also in body fluid matrices.

4.1.2 Recommendations

A drug specimen SRC ranked eighth among the 34 FSM classes, and is felt to merit further consideration. Many criminalists contacted expressed an interest in obtaining drug standards. "Drugs" ranked seventh in both Kingston's and Brunelle's surveys (appendices A and B).

4.1.2.1 Basic SRC Specifications

This SRC should consist of, minimally, some amount of every controlled substance. Those controlled substances more frequently encountered should be present in greater quantities than those substances infrequently encountered. Furthermore, commonly used drugs (e.g., aspirin, antihistamines, diuretics, etc.), though not of a controlled nature, should also be included. These would assist in defining the contents of noncontrolled drugs submitted for analysis. In this regard, cutting agents, common drug impurities and metabolities should also be made available as interest demands. The purity and concentration of each element should be given and certified where possible. The elements of this SRC should be generic drugs—differentiation by manufacturer is not required unless the respective products behave significantly differently under analysis.

Associated physical data and spectra are probably not required, since such data are available from many sources and would just add to the cost of this SRC.

4.1.2.2 SRC Sources

Drug sources include the DEA, the USP, pharmaceutical companies, the NCDC, confiscated drugs no longer required as evidential material, etc.

4.1.2.3 Implementation Factors

The first task of the developer is to precisely define the scope of the SRC. This can be done by survey or his own experience. Next, the developer must acquire the drugs. The drugs must then be assayed to determine their purity. If a drug is not sufficiently pure, the developer must further purify it. All drugs in the SRC should be of certified purity, and impurities should either be removed or quantified. The drugs can be made available in several ways: single drugs, groups of drugs, or a complete drug kit. The developer will need secure storage facilities and tight inventory controls.

The cost of this project will primarily go for drug purification and assay, and will be related to the SRC scope. At least two man-years and $120K would be required to complete all chemistry and certification.

The developer could market and sell the drugs himself. Alternatively, they could be transferred to the USP or NBS for dissemination.

4.1.2.4 User Factors

Only those crime laboratories that have been approved (licensed) by DEA should be permitted to purchase drugs from the developer/distributor.

4.1.2.5 Research Requirements

In addition to the determination of the basic requirements of crime laboratories; i.e., the SRC, scope required, purity of drugs, required drug forms, etc., some research into purification methodology will be required for some SRC elements.

4.2 Solid Dosage Drugs (Pill Identification)

4.2.1 Background

It was indicated (paragraph 4.1.1) that the individual (or agency) assigned to drug analysis is faced with a complex task. Fortunately, most domestically manufactured, solid dosage form drugs can be visually identified by their appearance (morphology, color, etc.) and/or identifying markings. An analyst's ability to identify the nature and manufacturer of a tablet or capsule will allow him to obtain, prior to analysis, compositional data and related physical characterization data. In this regard, the Physician's Desk Reference (PDR) is extremely valuable; indeed, almost all crime laboratories subscribe to this reference manual. The PDR, over 1,000 pages in length, contains 1:1 pictorial representations (in color) of between 1,000 and 2,000 unique, domestically manufactured, tablet and capsule-form drugs. Where different identification marks are given on opposing sides of a tablet or capsule, then both sides are generally presented. An explanation of marking codes accompanies each manufacturer's products. Only about 20 percent of the legitimate solid dosage drugs present identifiable markings, due possibly to a reluctance on the part of some manufacturers to identify their products. The photos are arranged alphabetically by manufacturer, and for each manufacturer by drug class or name. Thus, although there are over 1,000 tablets and capsules pictured, a match can be rapidly obtained where the manufacturer can be ascertained from the external markings. The PDR also contains compositional data (by weight or USP units) of the active ingredients, action, dosages, contraindications, and antidotes, where applicable. These data are also arranged alphabetically by generic, chemical or trade name, and cover drugs in all forms (i.e., liquid, solid and powder). Thus, the PDR is of potential use to those qualified personnel that come in contact with overdose victims, where the appropriate antidotes must be administered quickly.

The price of a PDR, $11, is well within any crime laboratory's budget.[2], The PDR can, in fact, often be obtained without charge and, since it is published annually, the photos and data presented are current. The PDR does, however, suffer a few drawbacks:

1) It does not contain data for tablets or capsules of foreign origin, though some of these are of significance to the drug analyst. Even for domestically produced drugs, the PDR is far from complete.

2) Matching a tablet or capsule without markings with a photo can be quite time consuming, since the PDR arrangement is not morphological.

3) The PDR does not contain representations of many of the tablets and capsules containing controlled or abused drugs.

Another useful book is the "Handbook of Non-Prescription Drugs" edited by George Griffinhagen and Linda Hawkins, published annually by the APA.[3] This book covers many over-the-counter drugs, whereas the PDR is principally concerned with prescription drugs.

The "National Drug Code Directory" lists those manufacturers who code their drugs and gives an explanation of the codes. Note that the "Drug Listing Act" of 1972 requires all manufacturers to list with the FDA the drugs they manufacture and the principal ingredients thereof. The FDA has yet to decide how these data will be published.

The total number of unique solid dosage drugs is difficult to determine. The FDA, Pharmaceutical Manufacturers Association (PMA), American Pharmaceutical Association (APA), National Pharmaceutical Council (NPC), "Drug Topics" and DEA were queried as to their estimates of the size of this population. Answers were either noncommittal or ranged from 2,000 to over 100,000. According to the "U.S. Industrial Outlook," 1972 (published by the Department of Commerce), the number of drug manufacturers in the U.S. is about 1200-1300. A survey of the PMA membership in 1970 indicated the total number of drugs of all forms manufactured by these manufacturers was about

[2] May be obtained from: Physician's Desk Reference, Box 58, Oradell,New Jersey 07649.

[3] Available from the American Pharamaceutical Association, 2215 Constitution Ave., Washington D.C. 20037 for $7.50. (Payment must accompany orders under $20.00).

14,000. Three points must be noted here, however: (1) some legitimate drug manufacturers may not have been represented in this survey, (2) the survey is not current, and (3) the fraction of the 14,000 drug types that are not solid dosage forms is unknown. If it is assumed that those drugs that cannot be purchased at drug stores, but are only administered by physicians, etc. (e.g., subcutaneous doses) are but a small percentage of this 14,000, then an estimate of the subpopulation of interest is still obtainable. From yet another survey it was observed that 47% of filled prescriptions were for tablet-type drugs, while 25% were for capsules. Thus, 72% of filled prescriptions were for solid dosage drugs. If we take this value to be representative of all drugs (prescription + over-the-counter (OTC)), then an upper bound for solid dosage drugs is $\sim$ 10,000. Of course, many of these are rarely found and as such could be excluded on the basis of infrequency of use. Similarly, many of these drugs enjoy but regional dissemination. It would appear that for a "pill SRC" to be comprehensive it should contain at least 5,000 elements. This would be unwieldly if not computerized, but still manageable. The value 5000 corroborates one drug analyst's[4] estimate that the PDR contains photos of less than 50 percent of the marketed solid dosage drugs, and therefore cannot be considered comprehensive.

Gupta and Kofoed, in 1967, published a book [GU–1] based on a 1962 Journal of the American Medical Association article [HE–2], which gave a possible classification scheme for solid dosage drugs based on their appearance. Another scheme for the rapid identification of tablets is described by McArdle & Skew [MC–3].

The development of a tablet and capsule SRC consisting of 1:1 color representations of commercially manufactured drugs in tablet and capsule form, and arranged in a classification scheme based on visually identifiable qualities received the second highest mathematical rating of the 34 categories analyzed (see table G1). This rating reflects the high potential utility of such an SRC, and the minimal estimated effort required to develop a satisfactory SRC. Several considerations not included in the mathematical analysis temper this rating somewhat. (1) The analysis does not take into account existent SRCs. For example, the McLean, Virginia branch of the DEA has developed, over a period of several years, a "pill" collection consisting of thousands of tablets and capsules of both commercial and illicit origin. It is estimated that a high percentage of all U.S. commercially manufactured "controlled drugs" are represented in this collection.[5] The Santa Clara County Crime Lab (at San Jose) has also developed a pill identification SRC containing both physical specimens and data cards. The approximately 1,000 specimens/cards in this SRC were obtained from a multitude of sources under the aegis of various caretakers (or developers); as a result, this file is neither comprehensive, current nor consistent. Nevertheless, it is used "almost daily" by the above laboratory, both for visual comparisons and, when this is not sufficient, for physical standards to run alongside "unknowns". (2) The percentage of controlled, abused, or dangerous drugs that are marked for easy identification, although not too great at present, is rapidly increasing. (3) Many different drugs have identical appearances. For example, many unmarked white, biconvex tablets, 9-10mm in diameter, cannot be differentiated by visual inspection. The same holds for standard gelatin capsules containing white powder. It is not known what percentage of common tablets and capsules fall into such "visually indeterminate" groupings. (4) Drug manufacturers specially mark some drugs for specific retail stores/chains, thus creating a multiplicity of markings for a single tablet or capsule.

4.2.2 Recommendations

The recommendation is made to further consider the development of a "pill identification" SRC. This recommendation is in accord with the mathematical treatment of Appendix G.

4.2.2.1 Basic SRC Specifications

The SRC should contain 1:1 color illustrations of current, domestically manufactured and

[4] Cecil Hider, Drug Analyst, Santa Barbara County D.A. Crime Laboratory, Private Communication.

[5] This SRC is accessed, however, in a manner completely different from that being proposed. That is, a pill of unknown composition is first chemically analyzed by DEA, and only then is their collection, ,which is arranged by generic drug class, searched for a match.

marketed solid-dosage form drugs, independent of their "controlled" status. Those controlled drugs manufactured either abroad or in the U.S. for sale abroad, but which have appeared on the U.S. "drug scene," should also be included. In particular, controlled drugs from Mexico, Canada and the United Kingdom should be considered for inclusion. Comprehensiveness is of great importance. Illustrations of the dosage forms should be presented according to a classification scheme that would permit search and identification even where identification marks are not present. As this SRC would be designed to be used in tandem with the PDR, Merck Index or the like, it need not contain other than trade and generic chemical names and the manufacturer's identity—that is, enough information to identify the active ingredients, and to permit accessing the PDR, etc., for additional data. The number of tablets and capsules included in this SRC would be about 1500-3000.

"Pill identification" and drug SRCs (see paragraph 4.1.2), in essence, complement each other. These SRCs need not, however, have a one-to-one correspondence of elements. Thus, a physical specimen drug SRC could contain samples of each generic pharmaceutical or drug, whereas a "pill identification" SRC should contain likenesses of each visually variant tablet and capsule. The former SRC could contain elements in tablet, capsule, powder, liquid, or even botanical form, whereas the latter SRC would only include those drugs available in solid dosage form.

4.2.2.2 SRC Sources

Most of the data can be obtained either from the PDR or equivalent foreign publications [BL–1, DR–1, PH–1, VI–2, etc.]. The manufacturers would probably be willing to supply missing data and photos, or actual sample drugs. A good source of foreign drug data is the publication "Unlisted Drugs," published by "Unlisted Drugs," Box 401, Chatham, N.J. 07928. This is a monthly publication identifying and describing those new drug products in the basic common drug reference compendia. The data are available in both magazine and index card formats.

4.2.2.3 Implementation Factors

The decisions as to the basic nature of the SRC can be those of the sponsor, the developer, or can be based on a survey made by either. Possible developers (or consultants to the developers) include Messrs. Gupta, Kofoed, Hefferen, Hastings, and DEA, the FDA, the publishers of the PDR (Medical Economics, Inc., the Pharmaceutical Division of "Special Libraries Association," Philadelphia College of Pharmacy and Science, Philadelphia 19104), etc. The SRC could take one of several forms:

a) An index card file, each card containing the likeness of a unique tablet or capsule and pertinent data (as defined in 4.2.2). The cards would be in a prescribed (cataloged) order and updating would then simply consist of pulling obsolete cards and inserting cards when new products or dosages enter the market.

b) A series of pages, each of which would contain data and likenesses for a series of tablets and/or capsules containing one or more common descriptive elements. Updating this form of SRC would involve the periodic publication and dissemination of a completely new SRC.

c) A combination of data cards and actual exemplars.

A card file form appears to be preferable, since updating would be simpler and could be done on a continuous rather than periodic basis. Either file would need to be supplemented by indexes which would cross reference the SRC elements with alphabetical trade and generic name lists, as well as an alphabetized manufacturers list. Purchase of a card file SRC could consist of a one-time payment for the base file and index, plus a maintenance contract. An SRC reissued annually could be purchased on a subscription basis.

The preparation of the SRC could be LEAA or DEA-funded, while the cost of printing the file and index could be borne by the subscribers. Subsequent updating costs could be borne by the subscribers or supplemented by a funding agency.

The principal factors affecting the time required to develop this SRC are: funding level; development of the search and identification methodology; and acquisition of data pertaining to foreign products. A development time of about six months at a funding level of from $30–50K is estimated. Printing could take another 3–6 months.

4.2.2.4 User Factors

The SRC should be made available to any individual or agency that has some connection with a recognized drug control program. Coroners, medical examiners, doctors, and emergency facilities that make frequent contact with overdose victims should also have access to this SRC.

4.2.2.5 Research Requirements

The principal research requirements are two-fold: (1) a survey to determine the scope, content and format of the SRC; (2) the development of a simple and rapid search and identification methodology. Collection of the pertinent data for each of the elements of the SRC, and cross indexing the SRC elements with those of the PDR, is also required.

4.3 Tobacco

4.3.1 Background

Physical object category #10 of appendix C (cigarettes, matches, related ashes) tied for seventh place out of 23 categories when ordered according to rate of occurrence at crime scenes. Benson's data (appendix D) do not include such a category, however. Unfortunately, due to a lack of knowledge of intra- and inter-variabilities in the composition of cigarette components, it was difficult to accurately assess the viability of an ash, filter, or cigarette paper (by brand) SRC. Since the number of elements in such an SRC would be quite limited, say 100, development of the requisite population statistics could be relatively inexpensive. However, the extremely broad distribution pattern for most of the elements of such an SRC reduces the potential value of cigarette evidential material (either for suspect development or corroboration), and further weakens the case for a cigarette SRC.

In theory, cigarette evidential material would appear to be more useful in eliminating suspects but, in fact, the potential for the misassociation of perpetrator and clue, and for the deliberate interjection of specious clues vitiate this approach.

Neither Kingston's nor Brunelle's questionnaires (appendices A and B, respectively) drew any responses indicating interest in a cigarette-related study.

Neither the development of a cigarette-related SRC, nor the evaluation of the population statistics is recommended at this time.

4.4 Alcohol

4.4.1 Background

Most city, county and/or state law enforcement agencies have extensive drunk driver testing programs. Often, the burden of the analysis falls on an associated crime laboratory. Alcohol intake can be measured by either breath, blood or urine analysis. Breath analysis can be administered by a highway patrolman using a portable, automatic breath alcohol analyzer; however, the remote collection and subsequent analysis by gas chromatography at a crime lab is also common. Blood or urine samples are analyzed by headspace—GC analysis, or other instrumental or chemical analysis procedures.

NBS presently supplies many crime labs with the potassium dichromate standards used for blood alcohol (BA) analysis. NBS is also developing ethanol primary standards which will be used to check local 'working' standards.

Three areas where work is recommended are (1) improvement of breath analyzers to the point where trained patrolmen can obtain rapid, accurate, on-the-spot BA level estimates which are acceptable as evidence; (2) improvement of the quality and reliability of the enzymes used in BAs (ADH, NAD, and Diaphorase); (3) an analysis of the accuracy of the various local BA testing programs by means of 'blind' standards (such as are used in California) or national round-robin type projects.

Although "alcohol" ranked sixth in the mathematical analysis, a "recommendations" subsection has not been included here since the development of an SRC is already in progress.

4.5 Cosmetics

4.5.1 Background

"Cosmetics" is taken to include powders, lipsticks, perfumes, hair creams, sprays or greases, etc. Note that Parker's survey (appendix C) does not even contain a specific "cosmetic" category, though it can be argued that many cosmetic residues could fall under the "organic substance" category. Benson's results (appendix D) also do not include a "cosmetics" category. All inquiries made in the course of this project indicate both a very low evidential caseload and value for cosmetic materials. Similarly, from appendices A and B, we note an essentially non-existent interest in the study of cosmetic evidence. Taking this in conjunction with the extensive distribution patterns and the very limited availability of characterization data for most cosmetic materials makes this category of forensic materials unacceptable, at the present time, for further consideration.

Note that the coloring agents used in cosmetics are included in the discussions of paragraph 4.17 (Dyes, Stains and Pigments).

The U.S. Customs, Varick Street Laboratory has an "essential oils" SRC consisting of several hundred samples of perfumes, perfume intermediates and related substances. Sadtler markets an SRC consisting of 214 IR spectra of principal components of those "Essential Oils" which have significant commercial applications. The cost of this SRC is $28.

Note [BA–1] on lipstick identification. The AOAC is involved with cosmetic composition and the analysis thereof.

4.6 Hair, Human

4.6.1 Background

Examination/analysis of human hair at present enables an investigator to determine its color, origin (part of body), the possible process by which it became separated from a body, and if the hair has been bleached, tinted or colored. Sex and age can sometimes be conjectured from morphological observations, but not with any degree of certainty. Some laboratories have been successful in blood typing hair (from 'secretors') and, if the hair follicle is present, sex determination is sometimes possible. Race determination, though useful for suspect development, is tricky and can generate erroneous conclusions. The morphological comparison of hairs, with few exceptions (notably those of Dr. Paul Kirk), leads only to qualifying statements as to their 'similarity' or 'dissimilarity.'

Morphological individualization of hair is at present not possible. Elemental analysis (utilizing AA or NAA, for example) is still in the developmental stage, but may someday lead to individualization capability, especially if combined with refined hair blood typing methoddogy. Apparently some private laboratories are presently doing AA analyses of hair samples upon referral of patients from physicians.[6] A study, using NAA on hair samples taken from two brothers over a 25-year span [CO-4], indicated that: for a given individual the concentrations of Cu and Zn in the hair remain fairly constant with time; As and Sb are fairly constant constituents; Au is quite variable, and is a function of several factors; and the concentration levels of several elements were found to differ among the brothers even when they resided in the same house. Most criminalists regard human hair as poor evidential material. However, from appendices C and D, it is seen that hair is often found in conjunction with homicides. Most crime laboratories have, therefore, rudimentary human hair reference files. These collections do not represent either open case of identification files, rather they serve as training tools for morphological (microscopic) analysis and, occasionally, for blood typing.

[6] The Washington Post of August 23, 1973.

As can be ascertained from the rating obtained by this FSM class in the mathematical analysis, the development of a human hair SRC is not recommended at this time. Nevertheless, the possibility of future developments augmenting the utility of hair as evidential material exists. Indeed, to quote from a John Jay College lab manual: "Hair probably enjoys the greatest potential applicability of all types of personal physical evidence, including latent fingerprints." Note that Brunelle's survey for the AOAC [appendix B] and Kingston's study of 1971 [appendix A] rank hair first and second, respectively, as evidential materials in need of further study. Aldermaston [CU–2] and other laboratories are proceeding with extensive programs aimed at developing improved means of hair characterization and new population statistics. Among the instrumental analysis methods being tried are P–GC, P–MS, nonflame AA, NAA, and others. If and when such programs bear fruit, a re-examination of this potential SRC should be undertaken. At such time, the utility of obtaining and filing hair specimens from convicted criminals, especially where the crimes involved are of serious or violent nature, is foreseen.

4.7 Hair, Animal

4.7.1 Background

Although animal hairs are not frequently encountered in crime laboratories, they can occasionally be related to illegal activities such as rustling and game law violations. The FBI examines over 1,000 animal hair specimens per year, and they feel that an animal hair SRC is more useful than its human counterpart. Many crime labs have rudimentary animal hair SRCs, and almost all criminalists contacted expressed a strong interest in obtaining such an SRC. A most comprehensive animal hair SRC is that developed by Walter C. McCrone Research Associates, Inc. This SRC contains hair samples from about 250 different, domesticated and wild, indigenous and foreign animal species. It contains samples from both male and female members of most species represented, and each sample includes both "down" and "guard" hairs from various parts of the animals.

A good book on animal fiber identification is that by Appleyard [AP–1]. Some data on animal hairs is probably available from the Association of Bedding and Furniture Law Officials (ABFLO).[7]

4.7.2 Recommendations

The decision to give further consideration to an animal hair SRC is marginal. It is felt, however, that since the demand for such an SRC is so widespread, serious consideration should be given to its development. As mentioned in paragraph 4.6, appendices A and B rank hair (albeit "human" in appendix A) first or second as forensic materials requiring further study. At the minimum, a research project is deemed worth undertaking.

4.7.2.1 Basic SRC Specifications

If and when a decision to develop an animal hair SRC is made, then the species to be represented can be based on a survey. General classes of animals that should be represented in the SRC are:

a) Domestic animal and bird species of significant population,

b) All animals, domestic and foreign, of legal import (i.e., protected, endangered and forbidden species),

c) Those animal species, domestic and foreign, whose pelts are used commercially.

The number of unique animals represented in this SRC should total about 100-150. Each element of this SRC should contain:

a) Enough strands of hair from each specie to indicate the intraspecie variants (e.g., sex, type hair, body area, random.) Duplicates should be included, where possible, and all strands from each specie enclosed in a sealed, well labeled, and numbered container.

b) A slide on which are mounted a selection of strands showing the variants. The strands could be end mounted, and the slide should be permanently labeled and numbered.

To complement this sample and slide SRC, John Delly of McCrone Associates, Inc. suggests

[7]Address: 270 Broadway, New York, N.Y. 10007.

the development of an "Atlas of Animal Hairs." This manual would contain photomicrographs of hairs and feathers of, minimally, each of the species and variations represented in the specimen SRC. These photomicrographs should include cross section and longitudinal section views. All pertinent characterization data, population statistics and significant variations between related species and within each specie should also be included. Characterization data should be given in statistical terms where intraspecie variations are significant. Legal considerations pertinent to protected species, etc., could be included in the atlas or put out as a supplement. The scope of this atlas could be greater than that of the specimen SRC. How comprehensive the atlas should be must depend on factors such as funding level, demand and time. Since both specimen and photomicrograph collections would be extensive, some thought should be given to classification schemes. Specimen and atlas SRC's should be completely cross-referenced.

4.7.2.2 SRC Sources

All potential animal hair and bird feather sources must be in a position to authenticate and document the samples they submit for inclusion in the SRC. The developer must, however, make independent checks of these specimens, where possible. Potential sources include the existing Walter C. McCrone Institute SRC, zoos (in particular, the San Diego and Bronx Zoos), veterinary schools, schools of taxidermy, furriers, furniture and bedding institutes, etc.

4.7.2.3 Implementation Factors

Acquisition and authentication of specimens, as well as any basic research into population statistics and specie variability, could be funded by one or more interested agencies such as LEAA, Customs, the Smithsonian, FDA, Department of the Interior, ABFLO, etc. Some physical specimens and characterization data could doubtless be obtained without charge from state and federal agency sources.

The costs of preparing sample packets, slides, and an atlas should be borne by the users. John Delly of Walter C McCrone Associates, Inc., believes that the market for both the sample SRC and atlas would be considerable; if so, the price of the sample and slide SRC could be kept to under $200, while that of the atlas should be about $75. All those listed as potential sample sources would also be possible purchasers of these SRCs.

4.7.2.4 User Factors

There does not appear to be any reason to place restrictions on the sale or distribution of either the sample SRC or the atlas.

4.7.2.5 Research Requirements

There are five aspects of the development of this SRC that could be classified as research projects:

a) By means of a survey or a series of consultations with AAFS members and other interested persons (say from Customs, Department of Interior, etc.), lists should be developed of those animal and bird species that should be included in the sample SRC and the atlas.

b) Animal hair characterization data must be obtained from the literature and/or the sources listed in 4.7.2.2.

c) Microscopic observations should be made on hairs from each sample and type of hair (by specie, sex, part of body, guard and down). Both cross section and longitudinal section observations should be made and photomicrographs taken. Microscopic observations as to color, dimensions, refractive index, birefringence, peculiar scale patterns, ranges, and any other morphological characteristics should be noted.

d) Where the differences in the microscopic appearance of hairs from two or more animal species are too subtle to permit differentiation, then other chemical or instrumental means of differentiation should be attempted. In particular, chemical reactivity, staining, fluorescence, P–GC, DTA, and atomic absorption can be tried.

e) All significant laws, restrictions, customs regulations, bounties, fines, endangered specie data, etc., should be obtained and correlated with the various elements of the specimen and atlas SRCs. This information could be included in the atlas, or could be issued as a supplement to it.

Potential researchers can come from the ranks of "sources" listed in 4.7.2.2. To be successful, however, this will probably have to be a cooperative venture involving several agencies.

4.8 Blood, Human

4.8.1 Background

Both human hair and blood evidential materials have high potentials for suspect individualization. But, whereas much research remains to be done before hair analysis becomes useful, it may already be possible to individualize a person by means of blood grouping based on a whole blood sample. To quote from a paper by Paul Kirk [LE–1, p267] ". . . no two persons are expected to have the same protein distributions in their bloods. The differences are both qualitative and quantitative, and the diversity of blood proteins is extreme." ". . . in theory, at least, even now the population of the earth can be divided up into 2.6 x 10^9 subpopulations . . ." A list of the known blood group systems can be found in Camp's monograph [CA–3].

Unfortunately, the criminalist must typically deal with dried blood samples which are of limited size, absorbed into various media, in varying states of putrefaction, and of unknown history (age, temperature and humidity conditions, etc.). Even with these limitations, blood grouping should permit considerable individualization of many dried blood stains. Due to a variety of reasons, this potential is seldom achieved. With few exceptions (such as Brian Culliford's group in the U.K.), crime labs test only for ABO, Rh and MNS groupings.

A somewhat casual examination of the serology aspect of forensic science indicates the presence of five problem areas:

a) The commercially available antisera are not of consistent efficacy or shelf life.

b) It is difficult to obtain samples of the rarer blood types to either check the efficacy of antisera or to run alongside unknowns. Some laboratories, such as Pittsburgh-Allegheny, have arrangements with a local blood bank, Red Cross unit, or hospital, to supply them with rarer type bloods, but many others have no such arrangement. Most labs obtain samples of the more common blood groups "in house" (e.g., from lab technicians, policemen, etc.).

c) Research leading toward the improvement of blood grouping methodology has, for the most part, been directed towards fresh, whole blood analysis. Methodology for grouping dried blood stains is still (at least in the U.S.) in a rudimentary stage [LE–1, p273]. Little has been written as to the effects of time, temperature, humidity, absorbing media, the effects of time, temperature, humidity, absorbing media, etc., on the typing of dried blood stains. Specific tests for small, dried blood samples should be developed, as should methods for blood typing by means of hair, nails, skin, saliva, sweat, seminal fluid and stains, and bone.

d) Although blood group data have been obtained for many individuals, little statistical analysis appears to have been performed on these data. Some population tables can be found in [CU–1, GI–1, HU–1, JO–4, KO–2, MO–2, MO–3, ST–1]. None of these references contain population statistics strictly relevant to the U.S. In particular, blood type percentage statistics are needed for the following U.S. population groupings: sex, race (see [BL–2]), ethnic background, secretors and demographic. Correlation coefficients among the various blood types must also be determined if one is to be able to make probabilistic statements based on blood grouping analyses. A plea for population statistics of blood groups has been made by Messrs. Gaensslen and Joseph [GA–1].

e) Most U.S. courts of law do not now admit blood grouping data other than ABO, MNS, and Rh. This problem is partially due to the problems mentioned above. It is hoped that once these problems are solved, then the acceptance by the courts of other types of blood evidence will be achieved.

The first four problems cited above are legitimate areas for further consideration, as is indicated by the high ranking (5th) obtained by this FSM class. It must be noted that Parker's study (appendix C) ranked blood very low in rate of occurrence at crime scenes. The rate of occurrence of blood at scenes where serious crimes had been committed was higher, however, than for other physical object categories. This conclusion is corroborated by Benson's data (appendix D).

Brunelle's survey (appendix B) ranks "biological stains" (the majority of which are assumed to be blood) 8th of 16 types of evidence in need of study. Kingston's study (appendix A) ranks "blood" 5th of 24 categories. The survey taken during the course of this project indicated a need, by the forensic science community, for work directed at correcting the problems indicated.

Many labs, such as the Sacramento County Crime Laboratory, have a significant paternity suit caseload. If the putative father is in fact innocent, then the probability of exonerating him based only on ABO, MNS, and Rh groupings is about 55 percent [CA–3]. The ability to further type blood (by PGm factors, etc.) could increase this probability. Positive identification of the father is not possible, at present, although the rarer the blood types involved the more definitive the conclusions can be. A paper by Lt. Col. Frank Camp [CA–2] suggests the possibility of a master data file on blood type for the general population. Of particular interest would be the blood typing of those individuals with criminal records, for potential use in suspect development or elimination.

The American Red Cross, the American Association of Blood Banks and the National Blood Banking Association all have blood donor registers. The first two have special registers for rare blood types.

4.8.2 Recommendations

A strong recommendation is made for the development of a publication containing blood type population statistics and probability tables. A reserved recommendation is made for the development of card files containing the names of potential donors of rare blood types. The development of a "master data file", as suggested by Camp, is not recommended at this time.

4.8.2.1 Basic SRC Specifications

Population statistics should present blood group percentages as a function of population class, and population class percentages as a function of blood group. Possible population class divisions are: geographical region; sex; race; ethnic background and secretor status. Such tables are found in [CU–1]. All blood types for which sufficient data exist should be analyzed, even if only a fraction of them are presently of use to criminalists. Tables of overall probabilities or methods of obtaining these from the given tables should also be given.

A lower priority should be assigned to the development of rare blood type donor files, and even then SRC development should only commence:

a) If it appears unlikely that methods of preserving whole blood (see 4.8.2.5) will become available in the near future.

b) For the use of those crime laboratories (or medical examiners) who are unable to obtain fresh whole blood from any local source.

These files should contain up to, say, five potential donors of each rare blood type. Name, address, and telephone number should be given, along with the blood type and name of the individual or agency that verified the typing. Age and general state of health should also be included, although potential donors too young, too old, or sick should not be included in the file unless other donors are not available. Space should be provided for a response record, giving the dates of requests and the responses obtained.

4.8.2.2 SRC Sources

Potential sources of both statistical and donor data include: the American Red Cross, the American Association of Blood Banks, the various military branches, the VA and hospitals. Research institutions such as NIH or Frank Camp's group at Ft. Knox may already have done some of the recommended analyses on existing data.

The Division of Medical Genetics, Dept. of Medicine, Medical School, Johns Hopkins Univ., Baltimore, Md., has in storage about 8000 blood samples statistically sampled from high school students across the country. Each sample is coded by age, sex, race, etc. ABO, Rh and some other typing has already been done, and this group would like to continue this project. Because these samples are more than 5 years old, some deterioration and hemolization can be expected to have occurred. They feel, however, that with the storage conditions used, Kell, Kid, Duffy and other groupings are still possible for the majority of these samples.

4.8.2.3 Implementation Factors

The statistical analysis of blood data should be carried out by a group that has extensive experience in data handling, computer programming and statistical analysis. The availability of statistical analysis computer software packages is also desirable. The task of developing blood population statistics could be done at NBS, utilizing the talents of the statistical engineering group and the NBS computer facilities. A consultant knowledgeable in serology should also be involved.

Funding for this task could come from any of the following agencies: NIH, a military branch, LEAA, etc. The cost of generating both population percentage, and marginal and correlation probability tables would depend on the availability and form of existing data. If the data are available on magnetic tape, punched cards, etc., then a 6-9 month project costing from $30,000-$50,000 is envisioned. Since blood population statistics should change but very slowly with time, this can be considered to be a one-time project.

The output of this project, a series of computer print-out tables, could be copied directly and made into a book. In this way, the cost of the book could be kept to under $20. The price of the book should not be such as to recoup the cost of the project, but rather to defray printing and distribution costs.

As for rare blood type donor files, all crime labs should be surveyed as to their need for such a service and their readiness to pay for such a file. The cost of a file could range from about $250 to $1,000, depending on the nature of the data base and its availability. Alternatively, the requesting agency could be sent the data directly for internal processing. A set of blank "potential blood donor" cards could be made available to the laboratory for this purpose.

4.8.2.4 User Factors

No restrictions are deemed required for a book giving blood group statistics and probability factors. Indeed, the greater the demand for such a book, the lower its cost could be.

As for potential donor card files, only those AAFS-selected agencies or individuals who could demonstrate the unavailability of alternate local sources of rare, whole blood specimens; and who are prepared to pay a service fee, should be considered for such files.

4.8.2.5 Research Requirements

The following areas of research are recommended for consideration:

a) Improvement in the quality of commercially manufactured antisera, possibly through the development or refinement of techniques, or through better quality control.

b) Improvement of the techniques for the long term storing of blood without deterioration. Lyophilization may be feasible. Revitalization techniques should also be investigated.

c) Improvement of the methods of determining blood type from the following substances: dried blood stains/crusts, hair, nails, skin, saliva, sweat, seminal fluid/stains, and bone. Many individuals and organizations are working on various aspects of this problem, some of which are discussed in articles [BL–2, CA–3, CU–2 and ST–1]. Coordination of these varied efforts is vital if duplication is to be avoided. No specific recommendation is made except that guided support should continue in the area of forensic blood grouping.

d) The development of blood group population statistics is of course, a research project, and has already been described.

4.9 Blood, Animal

4.9.1 Background

Animal blood is required to test the efficacy of animal antisera. No evidence was found that the typing of animal blood was being done anywhere. Animal blood is available commercially, and one criminalist surveyed (Bart Epstein of Minnesota State Lab at St. Paul) indicates that both animal blood and antisera remain stable when stored in a deep freeze.

The limited needs of most crime labs for animal blood are presently being met. No crime lab expressed any interest in obtaining such an SRC, and its development is not recommended.

4.10 Body Fluids, Human and Animal

4.10.1 Background

Blood and body fluids utilized for blood typing are essentially covered in paragraphs 4.8 and 4.9. Of the remaining fluids—urine, saliva, semen, sweat and tears—semen is of most interest. Indeed, urine can be considered as simply an interfering substance in the determination of alcohol and drugs in urine.

A criminalist is often called upon to determine whether a stain or vaginal sample contains human semen residue. Although there are chemical tests to distinguish semen from other substances, these tests cannot distinguish between human and animal semen. Dr. Alan Curry of the Central Research Establishment at Aldermaston recently developed and proved an anti-human-semen serum [CU–2].

The common method of identifying human sperm is by means of phase contrast microscopy.[8] Criminalists, however, are not sure whether they can differentiate, microscopically, human sperm from that of common animals. There appears to be a demand (indicated by this survey) for a very modest research project to determine the uniqueness of human semen/sperm. It should be noted that, although the study of "biological stains" was ranked 8th of 16 categories by Brunelle (appendix B), Kingston's survey (appendix A) ranked "body fluids" 19th of 24 categories.

4.10.2 Recommendations

This FSM class obtained an "indeterminate" rating in the mathematical analysis. The envisioned task of developing an atlas containing photomicrographs of human and common animal semina is a rather modest one; indeed, the requisite data may already exist. SRC recommendations are given with the tacit assumption that further information will be required to justify action. A principal reservation is the possible availability of antisera that would be highly specific for human semen. In this regard, Dr. Curry of the Central Research Establishment at Aldermaston should be contacted.

4.10.2.1 Basic SRC Specifications

This project would involve the microscopic comparison of human sperm with spermatozoa from about 15 animal species. Other factors, such as staining reactivity, RI, electrophoretic behavior, etc., could be considered in cases where the morphological differences between spermatazoa were too small to permit positive differentiation. Among the animal species that should be included are the horse, bull, sheep, goat, dog, rabbit, and pig.

A paper presenting photomicrographs of these selected spermatozoa should follow. It should also give associated characterization data where such were needed to identify positively the donor specie.

4.10.2.2 SRC Sources

Veterinary schools, zoos, and/or animal breeders could doubtless supply the needed semen samples. Such samples would have to be verified independently if such an SRC were to carry legal weight.

4.10.2.3 Implementation Factors

If a decision to proceed with such an SRC is made, then candidates for its development could be selected from veterinary schools, the Department of Agriculture, etc. The cost of such a project would range from \$5K to 15K and development time would run from one to three months, depending on the amount of data available at present. The output could be in the form of a paper published in a journal such as the Journal of the Forensic Science Society.

Photomicrographs of each spermatazoa specie should be shown, accompanied by a micrometer scale. These photomicrographs would be obtained using phase contrast microscopy and any special

[8] Standard tests for aspermal seminal stains include: Florence, human percipitin, acid phosphatase, and modified azo-dye.

conditions (e.g., staining, lighting, or filters) that permit more reliable differentiation of the various species. All useful characterization data plus test methods, storage procedures, etc., should also be given.

A set of color slide photomicrographs, similar to those included in the paper, would be quite useful as a training aid. Such a slide set might sell for about $10 or less.

4.10.2.4 User Factors

Since it is proposed to disseminate this SRC in the form of a paper in a journal available to the public, there appears to be no justification for restricting the sale of the slides or the dissemination of reprints.

4.10.2.5 Research Requirements

The research required will depend on the uniqueness of the various semina. If all species are morphologically distinguishable, then no further research is required. Where similarities occur, additional methods of differentiation, if not available from the literature, will have to be devised.

4.11 Prints (Finger, Palm, etc.)

4.11.1 Background

Dermatoglyphics, or fingerprint identification, has been used for many years, and many print files and retrieval routines have been developed. Nevertheless, it is felt that research into the desirability of weighting finger (or palm) print minutia (ridge characteristics) should be considered. At present, tradition requires twelve minutia matches [9] for an identification. Ridge characteristics include bifurcations, ridge endings, deltas, islands, dots, and short ridges. Since these minutia occur with different frequencies, the probability of making a match should depend on the specific ridge-type involved. That is, the total number of matches required—albeit a preset, arbitrary number—should be a function of the type of matches obtained. Thus, a match of 'islands' might count as 3 while a bifurcation match, if more common, could carry a weight, say, of ½. At present, automated optical scanning techniques exist but are only programmed to detect and match two types of minutia—bifurcations and ridge endings.

Kingston's and Brunelle's surveys (appendices A and B) rank the study of fingerprints low, or not at all. However, it must be remembered that these surveys were taken for ASTM and AOAC and may therefore be somewhat biased towards the study of physico-chemical systems.

4.11.2 Recommendations

Evaluation of this class resulted in a relatively high ranking (11th). The recommendation is made to consider supporting a study that would determine the relative frequencies with which each of the various fingerprint minutia occur and; based on this analysis, assign different weights to them.

4.11.2.1 Basic SRC Specifications

As envisaged, this project would begin with the selection of a random group of fingerprints. A minimum of, say, 500 sets should be obtained. If possible, optical scanning should be used to determine minutia frequencies. Minutia identification by means of optical scanning should, in fact, represent the initial project attempted. As many minutia types as possible should be made morphologically determinate by automatic techniques.

The frequency of appearance of each minutia type should then be determined. Possible correlations between ridge types and basic arch, loop, or whorl pattern assignment, and finger number could also be investigated.

If minimal correlations between basic fingerprint pattern or finger number and ridge type frequency of occurrence are found, then a simple weight assignment scheme will result. Weighting

[9] These are positional matches—that is, minutia are matched at identical positions on "known" and "unknown" fingerprints (for the same fingers).

factors are generally proportional to the squares of the relative frequencies. To avoid the drastic changes in present methodology that the generation of very large or small weights might incur, it is recommended that the range of the weighting factors be limited to between 0.5 and 4. The total number of "points" required for identification (typically 12) might remain unchanged, or could be raised or lowered, depending on the results of a series of 'blind' checks.[10]

The possibility of assigning a base point count to the total number of identification points, based on the occurrence frequency of the basic fingerprint pattern used to search a fingerprint file, should also be examined.

Note that the suggestions made here may have already been explored, and it would be incumbent on the funding agency to further research these proposals before making a decision. Note also that the recommendations all involve basic research and not the development of a true SRC.

4.11.2.2 SRC Sources

Each state and many cities have their own fingerprint files, generally numbering in the tens or hundreds of thousands of records. In addition, of course, there is the massive FBI file. It is probable that an accessible file can be located by the designated researcher.

4.11.2.3 Implementation Factors

Each of the areas of research recommended requires the inspection of actual fingerprint files. It is possible that removal or reproduction of elements of such a file may not be permitted and, therefore, data reduction may have to take place at the site. This could eliminate the optical scanning aspects of the project. Since the rapidity and ease with which the weighting project could be performed depends on whether the minutia sorting and counting is done manually or electronically, possibly both projects (weighting and scanning) will suffer if a suitable fingerprint file is not located.

Candidates for these research projects should include statisticians, computer analysts, and experts in optical scanning technology and dermatoglyphics. While NBS, Mitre and others have expertise in one or more of the first three categories, a fingerprint expert must be included in all phases of this project. Dr. Roche of The University of Southern California at Sacramento, who suggested several of the projects described here, might be willing to serve in such a capacity. Alternatively, a member of the International Association of Identification would be appropriate.[11] The president of this association, Lt. Byers, is a member of the Indiana Police Department. The AOAC may have some studies under way regarding fingerprint identification and should be contacted. This organization also may represent a possible source of SRC development candidates.

The funding and time requirements of each of the proposed projects depend to some degree on the accessibility of a fingerprint file. Rough estimates are given below.

phase	*brief description*	*time*	*cost*
a	Optical scanning	12–14 months	$70K–120K
b	Minutia weighting factors	No optical, 6–8 months	30K–45K
		With optical, 4–6 months	20K–30K
c	Base point count factors	2 months	10K
d	Required point counts	2–3 months	15K
e	Correlation factor	3–5 months	15K–25K

4.11.2.4 User Factors

There should be no restrictions on users.

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[10] This is in itself a worthwhile project—i.e., the determination of the number of identification points actually required to validate a match between known and unknown fingerprints at preset α and β levels (probabilities of making errors of first and second kinds).

[11] Address: 7 Parkway Pl., New Harvard, New York 13413.

4.11.2.5 Research Requirements

The research projects required by the recommendations of 4.11.2 are:

a) Determine the feasibility of using automatic optical scanning to detect and count all or more minutia types. In this regard, Messrs. Wegstein and Russel Kirsch of the NBS should be contacted.

b) Determine the optimal weight factors to be assigned to each minutia.

c) Determine whether 'base' values should be assigned fingerprint identification point counts. These values would depend on the frequency of occurrence of the basic fingerprint patterns.

d) Based on a series of realistic trials, determine the minimal point count that should be required for fingerprint identification, given α and β values. Note that α and β can be varied depending on whether the objective is to develop suspects or present evidential material in a court of law.

e) Determine the correlations, if any, between the frequency of occurrence of the various minutia and race, ethnic origin, and sex. Also, determine the correlations, if any, between these population classes and basic fingerprint patterns (arch, loop, whorl, etc.).

The results of these research projects could be disseminated as papers published in forensic journals. Advances in optical fingerprint scanning methodology could also be published in the appropriate journals.

4.12 Voice Prints

4.12.1 Background

Although voiceprint identification is still in its infancy, it has begun to gain in acceptance. Several states, including Michigan and California, are permitting the testimony of voiceprint experts in court. Since voiceprint identification is strictly a comparison technique, SRCs consisting of known criminal and open file voiceprints seem probable in the near future.

Development of population statistics would go far in:

a) Determining how well identification can be made over the range of variables (sex, age, region, accent, ethnic origin, etc.).

b) Determining the relationships between voiceprint features and region, ethnic background, race, age, etc.

c. The development of a cataloging system for voiceprints, followed by (possibly automated) search and retrieval methodology. The development of such a methodology must precede, or at least accompany, voiceprint record growth.

d) Quantifying marginal voiceprint dependencies on geographical region, sex, race, ethnic origin, age, etc.

All the above appear to be valid regions for research. Unfortunately, the available information is too limited to support objective recommendations. It should be noted, however, that the AOAC has assigned an Associate Referee, Ernest W. Nash of the Michigan State Police, E. Lansing, Michigan, to oversee the study of voiceprint identification. Thus, some of the above research projects may already be under way.

4.13 Paper, Writing

4.13.1 Background

"Paper" received a low rating in the mathematical analysis. The principal reasons for this are its broad distribution pattern, the large number of paper manufacturers and potential elements in such a SRC, the extensive effort that would be required to develop a data base, and the limited value of paper evidence in court. It should be noted that, according to Parker's survey (Appendix C), the rate of occurrence of paper as evidential material at crime scenes was 11th of 23 categories.

Brunelle's survey (appendix B) ranked "paper" 15th of 16 areas for future study, while Kingston's survey does not even contain a "paper" category, unless it is included within the "plant materials'' or ''wood'' categories which ranked 21 and 22 of 24 listings. The ATF has a unique paper identification caseload which might justify its development of a paper SRC.

Brunelle's pilot study [BR–13] indicates the potential of NAA to characterize paper. This investigator feels, however, that a good case for further study in this area has not been made. Schlessinger and Sette [SC–2] have developed some population statistics for paper, using NAA.

The McCrone Institute has a 500 element vegetable and paper fiber SRC consisting of both loose and mounted samples. The Institute of Paper Chemistry in Appleton, Wisconsin, has a pulp fiber SRC. If further consideration were to be given to a paper SRC, Irving Isenberg of this institute should be consulted. This institute sells wood, rice and grass fibers for 50 cents per packet. Another potential source of data is the American Paper Institute.[12]

4.14 Watermarks, Paper

4.14.1 Background

Although similar considerations hold for this class as for ''paper,'' the number of elements in this class is considerably smaller. Again, with the exception of ATF, there was little interest evinced for the development of a watermark SRC. Furthermore, several such SRCs appear to exist at the present time: (1) the FBI's ''Watermark File,'' (2) the Treasury Department's, (3) Phillips', and (4) the Lockwood watermark file.

It would appear that any further SRC development and dissemination should await the development of factors, such as legislation requiring periodic modification of watermarks, to make watermark identification more meaningful. Until such actions are forthcoming, the minimal utility of watermark identification must all but preclude the expenditure of significant resources on an SRC.

4.15 Typewriters, Typewriting, Ribbons

4.15.1 Background

The advancement of typewriter technology has created problems in the area of typewriter identification [HI–1]. The principal difficulties have arisen due to the introduction of the IBM ''Selectric'' concept, the proliferation of typewriter and typeface manufacturers, and the tighter engineering tolerances being met.

Custodian/Owner	*Comments*
1. United States Postal Service (USPS)	One of the best U.S. typewriting specimen SRCs
2. Ordway Hilton (pvt. QDE)	Principally U.S.
3. Donald Doud (pvt. QDE) Milwaukee, Wisconsis	Principally U.S.
4. Joseph Haas - Stuttgart, West Germany	Best foreign typewriting SRC
5. David Crown (QDE)	Principally U.S.
6. Zurich Police Dept.	One criminalist interviewed believed this department to be one of the world's best.
7. FBI's ''typewriter standards file''	Quite good; has manufacturing data.
8. NYC's P.D. Crime Lab.	Mostly for internal security; specimens from their own typewriters.

Most of these files are quite large, but none claims to be comprehensive. Each is considered proprietary by its developer. It is a full-time project to keep such files current, especially with regard

[12] Address: 260 Madison Avenue, New York, New York 10016 (see also paragraphs 4.19 and 4.20).

to manufacturing data. Thus, all QEDs contacted expressed a need for a comprehensive, current, typewriting specimen SRC.

Parker's paper [PA–1] does not cover this category (with the possible exception of "documents", which includes both handwritten and typed varieties, and which ranked 16th of 23 categories) since his survey only involves crime scenes that the police were called in to investigate. These were the scenes of rapes, robberies, murders, etc. Typewritten questionable documents, however, are associated with crimes that do not call for "crime scene" investigations. It has been estimated that less than five percent of the documents submitted to a QDE associated with a crime lab result from the search of crime scenes.[13]

Germany has recently legislated a requirement that all German typeface and typewriter manufacturers must alter their typefaces at least once every 4 years. Thus, for example, "RaRo" and "Olympia" now have built in dating mechanisms. This legislation would appear to have merit and, if enacted in this country, would, of course, have to include all domestic and imported typefaces and typewriters.

Very little recent information on typewriter ribbon identification was obtained, so that an analysis of the present status of this facet of questioned document examination was not possible.

4.15.2 Recommendations

This FSM class is recommended for further consideration. The mathematical analysis gave the typewriting SRC a relatively high ranking and it is believed that the demand for, and utility of such a file probably outweigh the great cost that its development could incur.

The possibility of developing a typewriter ribbon SRC also exists, although the utility of such an SRC is considerably more limited than that of a typewriting SRC. Some low priority consideration should be given to a research project to characterize typewriter ribbons.

4.15.2.1 Basic SRC Specifications

A typewriting SRC should consist of, minimally: an actual typewriting exemplar of each unique typewriter/typeface make and model, and possible combinations thereof. Domestic and foreign makes must be included in the file, and it should go back in time as far as possible (within cost and utility constraints). The file should be comprehensive. If a given typewriter/typeface combination is known to have significant variability in one of its identifying characteristics, then a series of exemplars, each taken with a different unit, should be included in the SRC.

Where significant variations in typewriting are generated by changes in ribbon, paper, stroke, etc., these variations should also be represented in the SRC.

The development of a permanent typewriter "museum" is not a requisite of this SRC, but would offer several desirable features (see paragraph 4.15.2.3). Foreign alphabet typefaces need not be included in the SRC, which is designed for domestic utilization.

4.15.2.2 SRC Sources

The typewriters required for generating exemplars can come from one or more of the collections listed in the table given in paragraph 4.15.1. Other sources are also possible, and the ASQDE, Interpol, etc. should be contacted in this regard.

4.15.2.3 Implementation Factors

A typewriting SRC will probably be best developed in series of ordered stages:

a) Acquisition or location of as many unique commercially available varieties of typewriters and typefaces [14] as is possible. Domestic and foreign varieties should be included, and the typewriters should date as far back in time as possible. Existing typewriter and typeface files would provide the best, initial sources for building an SRC. These files may possibly be acquired on a loan, purchase or lease arrangement.

b) Where possible, several units of each unique model should be used. The more recent and

[13] Jim Miller (QDE, D.C. Crime Laboratory), private communication.

[14] In particular, note the possible combinations of IBM "Selectric" typewriters and typeface elements.

popular a typewriter/typeface combination, the greater should be its representation. An upper limit of, say, 5 or 7 of each species would appear reasonable. The purpose of these duplicates would be to obtain an estimate of the variability of the various typewriting characteristics.

c) All pertinent manufacturing and distribution data should be obtained and authenticated, possibly by an ASQDE committee. The data should include the dates of production, serial number ranges, technical information, distribution patterns, etc.

d) Each unique typewriter/typeface species should be coded into an ASQDE-approved classification scheme. The basis of any such classification should be typeface characteristics; manufacturing and technical data should follow. A possible scheme for classifying and searching such a file is given in [GO–1], but others doubtless exist.

e) Typewriting specimens should be obtained for every possible typewriter/typeface combination. Ranges and unusual variations within each unique species should be noted.

f) The SRC user should be furnished with a set of volumes containing actual typewriting specimens [15]; pertinent technical and manufacturing data for each SRC element; an updating service; and a "special request" service. The special requests for typewriting specimens could be submitted with special paper supplied by the requestor, at his option. A nominal fee would be charged for these special services.

g) Standard paper, ribbon (a function of typewriter) and typewriting specimen formats must be agreed upon. The specimen format and practices used by Lowell Bradford's laboratory appears to be suitable. Other formats should also be considered, however. Where more than one specimen of a specific make and model of typewriter is accessed, and differences among the specimens are small, then the most representative unit should be used to prepare exemplars. If differences are large, then extreme-unit exemplars should also be included in the SRC. It may be possible to correlate variations in typewriting patterns, etc., with serial numbers. Such correlations could be quite useful.

h) Collation and cataloging of specimens, inclusion of manufacturing data, followed by printing and distribution. Existing classification schemes include those of Linton Godown [GO–1], Donald Doud ('63), Ordway Hilton, David Crown ('68), ASQDE, Joseph Haas, and Interpol. All such schemes are based on the following factors: basic typeface style (Monotone, Gothic, Nongothic, Pica); pitch (constant, variable); typeface manufacturer; letter height.

i) The custodians of any centralized typewriter/typeface collection would also be charged with updating the data base and with the collection, as well as processing of special requests. Since a preponderance of the potential users of such an SRC are located in the NE quandrant of the nation, the location for the repository SRC should probably be in this area.

Potential developers of such an SRC are an ASQDE committee, USPS, ATF, IRS, NBS. A recognized QDE should be called upon to head this SRC development project.

If the qualities of the various commercially available ribbons are such as to significantly affect typewriting characteristics, it may be necessary to add "ribbons" as an additional variable when obtaining specimens.

The development cost will depend heavily on the arrangements that are made to access typewriter collections. At worst, no collection may be accessable, and the developer will have to start from scratch. At best, a major collection might be donated or free access to it acquired. A summary of worst and best case cost and time estimates for SRC development is given below:

CASE	*TIME*	*COST*
Worst	2 years	$300,000
Best	$<$ 1 year	80,000

The effort required to produce the typewriting specimens might be recovered from the sale of the collections. The service contracts could also pay for themselves.

4.15.2.4 User Factors

Only members of ASQDE and other accredited individuals or organizations should be given the

[15] Note that photos, xerox or other copies of typewriting specimens are not substitutes for actual specimens.

option of purchasing the typewriting SRC, or the associated service. This is to prevent non-qualified people from attempting to do typewriter identification based on such a file.

4.15.2.5 Reserach Requirements

The research projects envisaged fall into three basic areas. The first deals with the acquisition and verification of all technical and manufacturing data for each typewriter/typeface element in the SRC. The second deals with the determination of the salient and distinguishing features that could permit the identification of each typewriter/typeface class. This would involve the taking of samples from each element and determination of the class ranges and variant characteristics. Finally, a classification scheme for quick referencing of the typeface file must be devised or agreed upon.

Much of the research has, no doubt, been performed by various QDEs. It remains to be seen how much of these data can be accessed.

4.16 Inks, Pens, Markers

4.16.1 Background

Three principal ink reference files are those of: the ATF, which contains more than 1300 inks (pen, ballpoint, fiber-tip, and stamp pad), including about 500 foreign specimens; the Zurich Police Department (under Werner Hoffmann); and the FBI.

The reason for ink's extremely low ranking in the mathematical analysis and in Kingston's and Brunelle's surveys (appendix A, 14th of 16 categories, and appendix B, 20th of 24 categories) are as follows:

a) The broad distribution patterns for most pens and inks.

b) The extremely poor population statistics for inks due to a lack of quality control; the primary factor controlled in ballpoint ink manufacturer is viscosity. Other factors of significance are the frequent fluctuations in ingredient sources, constituents and composition.

c) Due to the relatively inviolate nature of document evidence and the destructive nature of the ink analysis tests, the criminalist often has but a cut out punctuation mark to work with. Such a sample is often insufficient to perform a set of definitive tests.

There are 11-12 ballpoint ink and about 24 pen ink manufacturers in the U.S. Thus, it would appear that the situation is ripe for ink individualization (based on a comparison, say, of spectra or trace constituents), but the situation is poor for ink identification. Brunelle and Pro's paper [BR–4] appears to justify the utility of an ink SRC, either in the form of actual specimens, or as color slides of TLC plates taken with regular and UV light. The utility of such reference files, except as they point up the variability of, and similarities among the ink classes, is open to serious question.

Charles Hammer of the Analytical Chemistry Department, Georgetown University, claims that, for several reasons, one cannot make a positive statement concerning the identity of an ink. In addition to the reasons already stated, Dr. Hammer cites the absence of satisfactory methods of analysis. He feels that neither the TLC method nor the reference file used by the ATF are really satisfactory. He also indicated that no laboratory, to his knowledge, has ever tried to identify "blind" specimens.

Brunelle [BR–4], Dick [DI–2], Hamman [LE–2, p 379] and Veillon et al. [VE–1] describe the various methods of analyzing or identifying inks. These methods are useful in determining if a document has been tampered with, and could possibly date a document according to when an ink constituent was known to have been first introduced, or last used. These methods also serve to test the identity of a writing specimen and a suspect pen or marker. None of these tests, however, require an ink SRC, except as it may estimate the degree of variability among the various inks, and of any given ink.

Thus, the development of any form of ink SRC is not recommended for further consideration at this time.

4.17 Dyes, Stains and Pigments

4.17.1 Background

The dyes and pigments unique to paint and ink formulations are discussed elsewhere, as are stains due to blood. This section deals with those dyes, stains and pigments used to color food, drugs, cosmetics, garments, fabrics, woods, leather, and plastics. The U.S. Customs Bureau Office in New York City has extensive experience and expertise in dye identification, and particularly in the identification of benzenoid-type dyes. This Customs Lab (205 Varick Street) has several SRCs used in conjunction with test procedures for dye identification. One such file contains approximately 3,000 unique IR spectra of dyes and drugs. This file contains some spectra that Sadtler doesn't have (such as intermediates and new compounds from Europe and Japan) and vice versa.

Another file of note is the "Color Index." This is a set of 5 volumes published in 1971 by the Society of Dyers and Colourists in consultation with the American Association of Textile Chemists and Colorists (AATCC).[16] Volumes 1 to 3 present data on colorants, which have been classified according to usage and which are ordered by Color Index generic names. Uses include dying of fibers, direct and disperse dyes, food dyes, natural dyes, solvent dyes, pigments, etc. Volume 4 presents the various colorants according to their chemical constitution. Indices containing intermediate compounds and formulae are all found in Volume 4. Volume 5 gives dye and pigment manufacturer data, a generic name index and an index of commercial names of colorants in alphabetical order. The NBS issued McBee Keysort cards containing IR spectra data for commercial colorants until about 1960. These card files are no longer available.

The N.Y.C. Customs Lab has developed a collection of visible-range spectrophotometric data, covering about 3500 domestic and 1500 foreign dyes, pigments and intermediates in various solvents. Many duplicates are included in these 5,000 spectra, however. This file aids in both identification of colorants and in their quantification. This lab also has a series of card files containing visible spectrophotometric data. The McBee Keysort files are set up so that one can enter with peak locations and intensities and sort out candidate colorants. There is also a file for chemical class and for type of textile.

Standard identification and quantification procedures due to AATCC, AOAC, and ASTM exist for a great number of colorants and related substances. Books on colorants include [KO–1, LU–1, and VE–2]. The AATCXC also publishes "Textile Chemist and Colorist" (biweekly), "Technical Manual" (annual), and "Products" (an annual publication containing listings of American resin-bonded pigment colors and American-made dyes). Bette Hamman [LE–2, p379] describes the use of TLC, spectrophotometry, and chemical methods for dye and pigment identification. Neither Kingston's nor Brunelle's surveys contain a "colorant" category.

Since no responses or requests relevant to colorant materials were obtained from those surveyed, it was concluded that there is not sufficient need or interest in colorants to warrant any SRC development.

4.18 Fibers, Synthetic

4.18.1 Background

This class is restricted to those synthetic fibers that go into the production of fabrics for clothing, bedding, linens, and upholstery, as well as stuffings for mattresses, furniture, quilts, sleeping bags, pillows, etc. Animal and vegetable (natural) fibers are discussed elsewhere.

There is much literature on synthetic fiber characterization methods and on characterization data. The following references should be noted: BE–2, CO–2, CO–6, DU–2, KO–1, LU–1, RO–2, TE–2, and WH–1. Volume 4 of "Methods of Forensic Science" [ME–2] has a section on "Colored Fibers in Criminal Investigation." In addition, "Textile World" [17] annually publishes a "Manmade

[16] Address: P.O. Box 12215, Research Triangle Park, N.C. 27709.

[17] Address: 1375 Peachtree Street, (N.E.), Atlanta, Georgia 30309.

Fiber Chart'' [TE-1] giving physical data for the various synthetic fiber classes. ''Test Fabrics, Inc.'' [18] markets packets of swatches of various synthetic fabrics.

Groups active in synthetic fiber identification and characterization include:

a) Various ASTM committees (such as the D-13 Committee under John Fuzek) who have obtained IR spectra for various fiber classes.

b) Various AATCC Committees (such as that under Jim Wiberely of Beaunit).

c) The French Center for Textile Research, which is especially strong in microscopic identification.

d) The N.Y.C. Customs Lab. Fiber Group, under ''Midge'' Eaton, does extensive fiber identification for duty assessment.

e) Walter C. McCrone and Associates, Inc., also does fiber identification.

f) Aldermaston is presently developing a data file of pyrograms of synthetic fibers and rubbers [CU-20]. They are developing a system of color identification along the lines of Munsell, and are also generating probability statistics (possibly based on manufacturing data).

g) Synthetics manufacturers such as DuPont, Beaunit, etc.

h) According to Douglas Park of the AOAC, this group may also be involved in projects relating to fiber analysis.

i) The AAFS Subcommittee (of the Methods Committee) chaired by Dick Fox of the Midwest Regional Crime Lab, Independence, Missouri.

Each of these groups has, in the course of its work, accumulated a substantial number of synthetic fiber samples. Dr. Braham Norwick (of Beaunit Mills, N.Y.C.) estimates the number of man-made fibers (differentiated by polymer class, manufacturer, denier, etc.) at about 300. Representatives of the N.Y.C. Customs Lab estimated the number of unique generic classes (e.g., acrilan, viscose, nylon, polyester, acetate, orlon, etc.) at less than 30; DU-2 lists only about 10 general ''Synthetics'' classes and 36 trade name products, but this reference is dated 1961. TE-2 (1972) lists only 12 generic classes, but almost 170 trade name fibers. Convoluting filament type (bulk, staple, tow, mono, and fibrillated film) into the picture gives a total of 225 potential SRC elements. There are more than 50 domestic manufacturers of synthetic fibers.

Walter C. McCrone and Associates, Inc., has about 200 synthetic fiber specimens, both loose and mounted. The Dade County, Toronto, and Plymouth, Michigan, Crime Labs. are said to have good collections. The N.Y.C. Customs Lab. has approximately 50 man-made fiber specimens which, unlike the others, are principally of foreign origin. Baltimore's and St Paul's crime laboratories claim to have good amounts of some synthetic fibers obtained without cost from various manufacturers. Indeed, most manufacturers would probably be willing to contribute free specimens of each type of fiber or yarn they produce. The confirmation and certification of polymer class can and should be performed by the developer.

Methods of identifying fibers include morphology and birefringence (microscopic observation), IR, GC-FI, P-GC, specific gravity, solubility, chemical reactivity, XRD and dying characteristics. Odor upon combustion and other thermal properties such as MP and DTA [LE-2, p359] are also useful. DuPont, Calco, and U.S. Testing Co. market dye solutions that impart unique colors to various fibers and thus permit their identification. The identification of a fabric can also involve the determination of ply count, weave, blend (percent composition), etc. Although not of recent vintage, [DU-2] gives a good overview of the methods of identifying fibers.[19] AATCC fiber identification test methods include numbers 20-1972, 94-1969, and 20A-1971. ASTM test methods for fibers include D276, D2101, D540 and D236. American National Standards Institute test methods include ANS-LO14.131, ANS-LO14.33, and ANS-LO14.192. The ABFLO has these standard methods for determining fiber content: D-3, 7, 9, 10 and 14. The ''Manmade Fiber Chart 1972'' [TE-2] contains an excellent summary of the principal physical characteristics of synthetic fibers.

Sadtler markets the following relevant spectra collections:

[18] Address: 200 Blackford Avenue, Middlesex, N.J.

MATERIAL	TYPE SPECTRA	# SPECTRA	COST
Monomers and Polymers	IR Grating	4200	$1764
Monomers and Polymers	IR Prism	4800	1728
Fibers	IR Grating	250	105
Fibers	IR Prism	300	108
Polymers	NMR 60 MHz	300	126
Polymers	NMR 100 MHz	300	156
Polymers & Related Products	DTA	700	140

It is claimed that synthetic fibers are generally more consistent than their natural counterparts. The identification of either type of fiber may suffer from the processing that they are put through (e.g., dyeing, teasing, brightening, delustration, etc.). Denier and filament-type variations can further complicate the identification of synthetics.

Most surveyed criminalists expressed a strong desire for a synthetic fiber SRC consisting of loose fibers. "Fibers" ranked 6th of 24, and 9th of 16 "types of evidence," found in need of study by Kingston (appendix A) and Brunelle (appendix B), respectively. The case load for fibers can be implied from Parker's survey (appendix C) which ranked them (both natural and synthetic) 13th of 23 categories. Benson (appendix D) indicates that fibers occur quite frequently at the scenes of serious crimes.

4.18.2 Recommendations

The mathematical analysis gave the "synthetic fiber" material class a relatively high ranking—the 10th highest of 34 classes. In view of the additional data presented in paragraph 4.18.1, which support the mathematical analysis, it is recommended that the development of a synthetic fiber specimen SRC be given further consideration.

4.18.2.1 Basic SRC Specifications

The number of elements in a synthetic fiber SRC should correspond to the number of unique and distinct polymer classes. Since each manufacturer, due to process variations, generally produces a unique and recognizable fiber-type (or types), the number of elements in a synthetic fiber SRC should represent the larger (~ 255 element) group rather than just the generic classes (~ 12) or trade names (~ 36).

The features of each sample that most readily permit manufacturer and fiber-type identification must be determined and catalogued. "Features" are taken to mean qualities that permit differentiation by at least one of the test methods mentioned in 4.18.1

Since there will be a substantial number of SRC elements, a cataloging system should be used, involving the basic variables of generic class, manufacturer and fiber type.

Based on existing identification methods and the availability of the SRC for comparison tests, the developer should determine the optimum set of test procedures that will permit classification of each unknown fiber. Almost all manufactured fibers (unknowns and standards) will have been treated or finished (e.g., with mordants, dyes, delustrants, water- or dirt-repellants, etc.). Therefore, several possibilities can present themselves during testing:

	TEST PROCEDURE	
Finish	*Comparison*	*Classification*
Interfering	Must undo finish of unknown and standard, or devise alternate procedure that is finish-independent.	Must undo finish of unknown, or devise an alternate test procedure that is finish independent.
Non-Interfering	No problem.	No. problem.

[10] This bulletin [DU-2] can be obtained, without charge, from Dupont's Textile Fibers Department, Wilmington, Delaware 19898.

If finishes can also be determined, so much the better.

Just as with animal hairs (paragraph 4.7), a coordinated "atlas" containing photomicrographs, characterization and manufacturing data should accompany a synthetic fiber SRC. Much characterization data already exists. Unlike a one-time animal hair SRC, however, any man-made fiber SRC would have to be updated at least once a year if it is to remain current.

SRC elements can be developed in both mounted and labeled packet forms, but for economy's sake, the packets would suffice.

The possibility of combining synthetic and natural fibers into one fiber SRC is discussed in paragraph 4.19

4.18.2.2 SRC Sources

As indicated in paragraph 4.18.1, there should be no trouble obtaining free samples of the fibers in sufficient quantities, although they may have to be culled from a weave, or a finish may have to be removed. Fiber sources will include both manufacturers and those labs that have already accumulated some specimens and are willing to donate them. All crime labs should be canvassed in this regard. Note that both the Toronto and Aldermaston crime laboratories are said to have significant synthetic fiber SRCs.

4.18.2.3 Implementation Factors

Significant interplay between the developer and manufacturer will be required to certify each specimen. The cost of acquiring and certifying fiber samples should be nominal—estimated at $10,000 and 2 months. The next steps are more complex and indefinite. An optimal set of test procedures will have to be developed. Most of the procedures will either come from the literature or involve comparison observations and, as such, will minimize the effort required. Where the fibers obtained have been treated in such a way that the imparted finish or quality "interferes" with the optimum identification procedure, either the treatment will have to be undone or the method revised. The costing for this aspect of the project should be approximately $25,000-$30,000 and 5-6 man-months.

The development of an atlas to complement the specimen SRC will depend on the availability of an existing equivalent, such as [CO–1 or TE–2]. Possibly the SRC could be referenced to existing sources of data and photomicrographs.

4.18.2.4 User Factors

There appears to be no reason for restricting distribution of either specimen or atlas SRCs. Indeed, appropriate nonforensic markets for both appear to exist.

4.18.2.5 Research Requirements

Much of the methodology has undoubtedly already been developed. What will be required is its extraction and convolution into the specimen SRC. Between 5 and 6 months could be required for this analysis.

The characterization data, if it is deemed necessary, can also be extracted from the literature.

Once the fiber specimen SRC has been developed, the potential for developing a set of procedures covering both natural and synthetic fibers will exist. These could further augment the ability of crime labs to identify fibers. Before starting on this project, a check on Aldermaston's status should be made.

4.19 Fibers, Plant

See also paragraphs 4.13, 4.18 and 4.20.

4.19.1 Background

Some of paragraph 4.18.1 applies to this section, particularly the comments about reference sources and finishes. Since this category, unfortunately, cuts across both "paper" and "wood" categories, some overlapping between the respective sections is unavoidable. Dr. Norwick estimates the number of plant fibers that have been used commercially at over 100, while Customs (Tony Johnides) claims the number may be as high as 500.[20] The number of plant fibers that appear commercially today in any significant quantity is probably well under 100.

The principal identification procedures include morphology, odor upon burning, flame, ash, staining, and solubility tests.

Since the number of plant fiber classes of commercial value is modest, and the class list remains relatively stable, many plant fiber collections exist. The Bronx Bontanical Musuem has, possibly, the best plant collection in the world. This museum receives about 100,000 new samples each year, of which about 150 are new species. Mr. Pardue of this museum claims that these samples, if properly stored, will last indefinitely. This museum also provides a free service of plant identification upon request. However, their response time may be too slow for some criminalists. The Botanical Museum of Harvard Univ., under Dr. Schultes, also has a large collection of preserved plants. This collection, consisting principally of plants of economic value, contains specimens representing unique species. The N.Y.C. Customs Lab has about 100 plant fiber specimens, mostly foreign in origin, and many of little commercial import. McCrone has an SRC consisting of over 500 samples (with duplicates) of plant and wood fibers, in mounted and loose forms. The Paper Institute has an extensive wood fiber SRC. Toronto's Crime Lab developed a good collection, but lost interest a few years ago. Recently, their interest has been renewed, and they have expressed a need for a good SRC.

Plant fibers are generally more variable, morphologically, than their synthetic counterparts [BE–2, CO–5, DU–2, EN–1 (Vol. 1), KO–1, LU–1, MC–2, and TE–2].

Five organizations were found to be both knowledgeable and willing to accept occasional fibers for indentification. They are: The Paper Institute, N.Y.C. Customs Lab., N.Y. Bontanical Museam, the Botanical Museum of Harvard and the FBI. The Textile Research Institute,[21] appears to be quite competent, but it is a commercial organization. The U.S. Testing Co. performs many tests on natural and synthetic fiber materials, some of which can be classified as fiber identification. In addition, this company tests and certifies "fugitive tints." These are compounds used by industry to identify blends, twists, yarns, lots and fabrics.

Parker's survey (appendix C) includes both "fibers, natural and synthetic," and "clothing" categories. Their rates of occurrence at crime scenes resulted in respective rankings of 7th and 13th, of 23 categories. Benson (appendix D) indicates a high incidence rate for fibers at rape scenes. As mentioned in paragraph 4.18.1, Kingston (appendix A) and Brunelle (appendix B) rank "fibers" 6th of 24 and 9th of 16 categories, respectively, in need of further study.

Except for McCrone's rather limited "Reference Set #2,", containing about 27 natural fibers, no documented, comprehensive set of natural fibers appears to be sold commerically.

4.19.2 Recommendations

The recommendation is made to give further consideration to the development of a physical specimen, plant fiber SRC. Depending on existing literature, an accompanying atlas may, or may not be required. (For example, see the "Index Herbariorum"). This category received a nominal rating in the mathematical analysis but should be given consideration as development resources allow.

4.19.2.1 Basic SRC Specifications

A plant fiber physical specimen SRC must be compatible with any other SRC that may be concurrently developed. That is, if wood, plant and synthetic fiber SCRs are to be developed, then the three should complement each other without substantial duplication.

In the following discussion, the concurrent development of three fiber SRCs (animal, synthetic and plant) is assumed.

A plant fiber SRC should contain about 70–100 elements and, specifically, plant fibers that occur with the highest frequency in household goods and personal attire. A list of potential elements

[20] This value may include animal fiber species.

[21] Address: Box 625, Princeton, N.J. 08540.

would include, therefore, jute, cotton, flax, linen, ramie, sisal, hemp, pig bristles, horse hair, etc. Silk, although not a plant fiber, could be included in this group. The elements must be available in "loose" form in labeled packets. Each element must be checked and certified possibly by the developer. Mounted slides should also be considered. Where significant variability exists within a given class of fiber, an indication of the class dispersion should be included. Thus, a sisal sample should contain fibers from different plants, and, if possible, from different sources or areas. Each variety within a given generic class should be represented if it is of economic value, and is significantly different from its intraclass neighbors.

4.19.2.2 SRC Sources

Possible sources of fibers include the N.Y. Botannical Museum, the Botanical Museum of Harvard Univ., the U.S. Customs, the Paper Institute, the AATCC, the ABFLO, etc.

4.19.2.3 Implementation Factors

If it can be assumed that one or more of the above SRC sources would donate sufficient quantities of most of the fibers required, then development cost and time can be primarily utilized to certify the SRC elements. In this case, development of the SRC could involve from 2–3 months at a cost of about $15,000. If a satisfactory source of photomicrographs exists, then no extensive data file need accompany the specimens. In this case, the cost of individual SRC sets could be kept to under $50. If it is found advisable to produce a coordinated "atlas" or data card file, the total cost of the SRC could go to $100, and development time would increase to 6–8 man-months.

Since the list of plant fibers used commercially is rather static, and since these fibers are not prone to decompose when stored correctly, it would be desirable to make this SRC a one-time effort. Therefore, the scope of the SRC should be as broad as possible. This would also increase its potential market (e.g., to include universities, argiculture schools, etc.).

4.19.2.4 User Factors

No restrictions should be placed on the distribution of this SRC.

4.19.2.5 Research Requirements

The only research foreseen, if it has not already been done, is to determine which finishes, dyes, etc., interfere with plant fiber identification, and how to eliminate or bypass these interferences.

4.20 Woods, Barks

See also paragraphs 4.13 and 4.19.

4.20.1 Background

The "Forest Products Laboratory" (FPL), Department of Agriculture, Forest Service, in Madison, Wisconsin, probably has the largest wood specimen collection in the world. Their collection comprises over 26,000 unique specimens, each 12" x 3" x 6". Excess specimens are given away free upon request. Unfortunately most excess specimens represent the more exotic species, which are of little commercial value. Although there are only a few woods that are extensively used, today's manufactured products utilize a multitude of woods from all over the world. Thus, it would be essentially impossible for any but the largest labs to have a "comprehensive" wood specimen SRC. In addition, wood identification is quite difficult. DR. R. Koeppen of the FPL claims that it is virtually impossible for a scientist to accurately classify wood unless he is specifically trained in this area. On the other hand, the FPL has the experts and offers a free wood identification service. A notarized, sworn statement is provided with each analysis. The FPL identifies over 2500 samples per year for various clients, including crime laboratories in Michigan, Wisconsin, Minnesota, etc. Another knowledgeable group is the National Forest Products Association.[22]

[22] Address: 1619 Mass. Ave., N.W., Washington, D.C. 20036.

Very few criminalists interviewed requested any effort along the lines of a wood SRC. Kingston's survey (appendix A) ranked wood 22 of 24 materials and Brunelle's survey (appendix B) does not even contain a "wood" category.

A few crime labs (e.g., the Los Angeles County Sheriff's Office, and Sacramento County) have small wood SRCs, but claim little use of them. The FBI has a wood specimen SRC which is marketed as the "Commercial Woods of the U.S."

Further consideration of a wood/bark SRC is not recommended.

4.21 Adhesives

4.21.1 Background

A comprehensive source of manufacturing data is available from the annual "Adhesives Red Book" [AD–1] and "Adhesives Age" [AD–2] is a useful monthly publication. The ASTM has many adhesives tests in their manuals but few, if any, deal directly with adhesive identification. The Smithsonian Science Information Exchange has abstracted the adhesives field.

If information regarding adhesives is required, the following groups can be contacted:

a. The Adhesive and Sealant Council, Inc.
   1410 Higgins Road
   Park Ridge, Illinois 60068
   (312) 825–8196
b. The ASTM
c. The Forest Products Research Society
   2801 Marshall Court
   Madison, Wisconsin 53705
   (608) 231–1361
d. The Pressure Sensitive Tape Council
   1201 Waukegan Road
   Glenview, Illinois 60025
   (312) 724–7700

This last group publishes, annually, the "Tape Directory."

Very little input into this category was obtained from the lab survey or from a scan of the forensic literature. Brunelle (of the ATF) claims to have run into cases involving adhesives only about five times in the last five years. Both Kingston's and Brunelle's surveys (appendices A and B) obtained no responses for adhesives. Parker's survey also does not contain an "adhesives" category. This category is not recommended for further consideration, since little need for such an SRC is evident.

4.22 Soils

4.22.1 Background

Much of the following information has been taken from a survey conducted for the NSF-SOS (Student Originated Studies) Forensic Soil Analysis Program at Michigan State University, East Lansing, Michigan 48823. These data represent a tabulation and analysis of 73 responses to a questionnaire sent to 184 criminalists laboratories in June 1973.

Fifty-six respondents reported performing from 2 to 50 soil analyses per year, the median being 10. (This is consistent with Parker's survey [PA–1], which reported that the rate of occurrence of soil residues (of potential forensic value) at crime scenes was 12th of 23 selected FSM categories.) These labs analyzed soil samples in connection with the following crimes: Burglary (33), Homicide (20), Rape (12), Larceny (9), and Assault (1). Shoes were the most likely source of samples, followed by clothing, automobiles, tools, etc. Sampling variables included collection mode (random, alibi, grid), type of container (airtight, aerobic, envelope, etc.), and sample preservation methodology.

The labs performing the soil analyses had the following qualified personnel:

qualifications	*no. of labs*[23]
Soil Specialists	10
Degrees in Chemistry	28
Forensic Science Degrees	20
Degrees in Geology	5
Special Training in Microscopy	12
Other Special Training	17

Some of the above training had been obtained at the various universities and some through courses given by various law enforcement agencies (e.g., the Honolulu Police Department). Institutions and agencies having expertise in soil analysis include: the JPL, Pasadena, California; Petroleum Laboratories; State and Federal Geology, Mining and Interior Departments; and the FBI.

According to the aforementioned survey, the methods employed in soil analysis were as follows:

METHOD OF ANALYSIS	NO. OF LABS REGULARLY EMPLOYING THIS METHOD
Optical Microscopy	51
Density	43
XRD (powder	13
Emission Spectrography	10
IR Spectroscopy	5
Biological Studies	8
AA	3
TLC or GC	2
NAA	1

The laboratories that reported using the above methods of analysis "occasionally" were not included in the above table. Nine labs reported the use of other techniques, including DTA, thermoluminescene [IN–1], electron microscopy and X-ray fluorescence. Brunelle et al. [BR–3] claim that about 20 chemical elements in soil can be identified and measured with "good precision and accuracy" using NAA and AA methods. In an earlier paper [HO–3], Hoffmann, Brunelle & Snow, using NAA and AA, showed how elemental composition varies geographically. This variability works both to the advantage and detriment of the forensic scientist. The disadvantage is principally that an almost infinitely small data grid would be required to establish an SRC. The advantage of this variability is the uniqueness imparted to any grid point. That is, if the elemental composition of an unknown sample and a known soil are the same (within tolerances) with respect to say 10 or 20 elements, then a good case can be made for the statement that the two came from the same location [LA–1].

With regard to the forensic value of soil, the Michigan State Univ. survey states:

"Three labs reported difficulties in presenting soil analysis results as evidence in the courtroom, and 51 reported no such difficulties. However, many respondents qualified their answers by referring to the weakness of soil analysis results as evidence. For instance, a number of labs mentioned that soil results are not of value unless supported by other evidence, and are not capable of establishing more than mere "similarities" between soils. One lab described soil as "the worst evidence we use."

"Twenty labs use soil analysis mainly as an investigative tool, 12 labs use soil mainly as actual evidence in the courtroom, and 10 reported an equal distribution between the two.

"Ten labs believe that it is currently possible to individualize soil samples, three labs believe that soil individualization is possible only under special circumstances, and 40 labs believe that individualization is currently impossible."

An interest in soil identification is, however, present. Brunelle's survey [BR–12] ranks "soil"

[23] A lab or individual may be represented more than once.

3rd of 16 types of evidence in need of study, while Kingston's survey ranks soil 4th of 24 categories. The Toronto Crime Laboratory has expressed an interest in a soil SRC.

Most Michigan State University survey respondents expressed a need for better soil comparison tests and indicated some degree of dissatisfaction with the available techniques. Also, according to this report:

"Seven analytical techniques were rated from 1 to 4 for both feasibility and adaptability. Ratings were multiplied by number of occurrences, as a means of ranking the techniques. Feasibility rankings are as follows:

1. Atomic absorption
2. Biological studies
3. X-ray powder diffraction
4. Neutron activation
5. Infrared spectroscopy
6. Gas Chromatography
7. Thin layer chromatography

Adaptability rankings are as follows:

1. Thin layer chromatography
2. Infrared spectroscopy
3. Gas chromatography
4. X-ray powder diffraction
5. Atomic absorption
6. Biological studies
7. Neutron activation."

It is felt that the field of soil analysis and identification is ripe for further research. Possibly maps, presenting percent composition isopleths of those elements whose concentrations most strongly correlate with location (e.g., La, Sn, Sb), should be generated for each state.

At the same time, geographical and temporal variability essentially eliminate soil as an SRC candidate. One possibility, which is not being recommended at this time, is the development of soil samples of known elemental compositions. These would permit the various labs who do soil analyses to check the validity of their procedures.

4.23 Glass, General

4.23.1 Background

All glass objects, with the single exception of auto headlight lenses, are included in this section. (Headlight lenses are covered in paragraph 4.24). The basic properties of glass and the methods for their determination are:

a) Refractive Index typically measured with an Abbe-type refractometer, or with a microscope using the "Becke line" immersion method. Although the AOAC may adopt the "Emmons Double Variation Method" [MC–1], with a precision of about $\pm 2x10^4$ RI units, a precision of $\pm 3x10^6$ RI units is claimed for the "Mettler Hot Stage" method [OJ–1, OJ–2].

b) Dispersion—also determined by the Abbe refractometer or Becke line methods, using a variable wavelength light source.

c) Density—the accepted method is the ASTM "Sink-Float Comparator" method [AS–2]. A standard deviation of 1×10^{4} g/cm is associated with this method.

d) Chemical Composition—as percent metal oxides (including Si, A1, B, Ca, Mg, K, N. Zn, Ti, and Pb oxides).

d) Coefficient of Thermal Expansion—(Seldom used by crime laboratories). A related technique is DTA, which can be used to determine glass transition temperatures [LE–2, p359].

f) Fluorescence—This attribute of some glasses is readily detected using UV light. X-ray fluorescence may also prove useful in the detection of trace constituents in glasses.

g) Thermoluminescence [IN–1].

The principal methods used by criminalists are a, b, and c. Unfortunately, due to stresses developed in glass during cooling, both density and RI have variances considerably greater than the uncertainties of the respective tests [DA–1, FO–2].[24] These large variations are not only between manufacturers, but among lots and even within single specimens. Other factors contribute to these variations, such as melt inhomogeneities, raw material variations and thermal history. The utility of the three basic measurements (a, b, and c) are: (1) if the evidential material differs substantially in one or more properties from the comparison sample, then the two can be said to be dissimilar (i.e., not from the same object); (2) if the two agree extremely well in all aspects, then they can be said to appear "similar." As described by MacDonnel [MA–2], the physical values determined may also enable the analyst to determine whether it came from a window, headlamp, light bulb, bottle, eye glass, etc.

A more uniform glass technology has resulted in decreasing the inter-company variations in RI and density [OJ–2].[25] The utility of RI and density measurement has, therefore, been somewhat diminished. Note, however, that some window glass is now imported from Belgium and France (and possibly other countries), and it is not known how their physical properties compare with those of American glasses.

Based on the large internal variability, the probable RI differences among the manufacturers, and the rather broad distributions of most commercial glasses, it would appear that RI and density measurements on evidential glass have little practical value. The mathematical analysis of this material class produced a quite low rating.

A suggestion has been made by Dr. Roche, of the University of Southern California at Sacramento, that glass samples be annealed before their properties are measured. This would remove major stresses, and thence, some of the internal physical variations. This process could improve the reliability of glass fragment comparisons, especially where the fragments have not come from contiguous parts of an object [HA–2].

Elemental composition, although used by Corning [MA–2], Aldermaston [CU–2], Vienna, Austria, [NE–1] and others [GE–2] to characterize glasses, is not used by many American crime laboratories other than the FBI and ATF. Since many companies use various trace elements (arsenic, for example) in the production of glass, the quantification of these might permit manufacturer identification. This possibility will not be realized until someone develops the composition population statistics required to judge how to differentiate glass by manufacturer (and possibly by function). Emission spectrometry and spectrography are good methods of determining glass composittion [LA–1, WI–2].

Fluorescence methods, as espoused by Dabbs [DA–1], should be explored for glass produced domestically.[26] Any project involving glass population statistics should include fluorescence as one of the properties measured. Similarly, thermoluminescence may serve as a technique for characterizing glasses [IN–1].

Obviously, RI population statistics are required as functions of manufacturer, type of glass, lot, unit and time. Dispersion, density and fluorescence population statistics should be measured next. If these physical properties prove indecisive in identifying both type and manufacturer of glass fragments, elemental analysis should be considered.

If, based on population statistics, refractive index and/or dispersion prove valid means of individualizing glass, then high precision measurements are in order. In such an event, it will be necessary to accurately calibrate refractometers. Standards of known RI and dispersion should then be made available to all crime laboratories.

The analysis of the general glass category (23) deals only with this potential standard need. Annealing was not considered, and the result, a very low rating, is due in part to glass' assumed large variabilities.

If elemental analysis is seen to be required for glass identification or individualization, then the possible need for glass composition standards (such as NBS' SRM 610 through 619)[27] These

[24] The large variation in headlight lenses found by Ojena and DeForest is discussed in 4.24.

[25] Extrapolating from Ojena's results for headlight lenses.

[26] Criminalistics Laboratory, Contra Costa County Sheriff's Office, Martines, Calif., has found that about 10 percent of the domestically manufactured glass they tested fluoresced.

[27] The existence of these standards should be made known to crime laboratories in the U.S. and abroad.

standards would be used to calibrate AA, NAA [SC–1], spark source MS [GE–2], and other types of analysis.

Inspector L. G. Nickolls of New Scotland Yard has stated (1962) that "The substance of greatest interest among manufactured materials found in the investigation of crime is glass." Brunelle's survey [BR–12] ranked glass 5th of 16 types of evidence and Parker's study [PA–1] ranked glass 4th of 23 categories in terms of rate of occurrence. Nevertheless, due to unanswered questions and the lack of sufficient population statistics data, no SRC development is recommended at this time. The research described above should, however, be funded and could easily lead to a re-evaluation of this category. Note that, as a result of their research, the AOAC may officially adopt a microscopic method for characterizing glass [BR–3].

It should also be noted that a source of glass standards already exists, namely the Schott Optical Glass Co., Duryea, Pennsylvania. They supply glasses of various types and refractive indices. The accuracy of their RI varies from $\pm 3x10^5$ RI units ("standard measurements") to $\pm 5x10^6$ ("extra precision measurements").

Pearson et al.'s project [PE–1], described in paragraph 4.25.1, also involved the determination of "background levels" for glass fragments. Further study of "ambient" or "background levels," involving determination of the basic physical characteristics generally used to identify and individualize glass fragments in outer garments (including shoe soles), would appear to be a worthy project. Since some date already exist further analysis is not being recommended for immediate action; nevertheless, such "background level" projects for glass (as well as paint, fibers, hairs, etc.) may merit future consideration.

4.24 Glass, Auto (and Plastic Lenses)

4.24.1 Background

Almost all the discussion of paragraph 4.23 applies equally to 4.24.

Crime laboratories are often called upon to examine physical evidence obtained from the scenes of hit-and-run accidents. Such accidents often result in the breaking of headlights (as well as in the transfer of exterior paint [paragraph 4.26]).

There are two U.S. manufacturers of glass for sealed-beam lamps: Corning and General Electric. The Corning glass factory in Greenville, Ohio, produces #7251 borosilicate glass for headlights. All of Corning's production is used by three lamp makers: Wagner Electric (Tung-Sol), Guide Lamp and Westinghouse. G.E.'s headlamp glass, #725, is also borosilicate. This glass is produced in two plants, each of which feeds most of its production to a G.E. lamp-making plant. The Mahoning glass plant at Niles, Ohio, feeds the Trumbull lamp plant in Warren, Ohio, and the Somerset glass plant (a high volume plant) in Somerset, Ky., feeds G.E.'s Lexington, KY., lamp plant.

The four U.S. lamp makers hare the American market roughly as follows:

Company	*Percent Original Equipment Trade*	*Percent Replacement Trade*
Wagner	20	30
Westinghouse	10	20
Guide Lamp	50	10
G.E.	20	40

There are six types of sealed beam lamps available on the market, exclusive of tractor, 6V, "Iodide" and other special lamps that account for only a very small percentage of the lamps on the road. These lamps are:

lamp no.	*o.d.*	*type*
4000	5 ¾"	Low Beam (replacing 4002)
4001	"	High Beam
4002	"	Low Beam (phasing out)
4004	"	High Beam
6014	7"	Twin Beam (replaced 6012 and 6013
6015	7"	Twin Beam (heavy duty, for trucks)

All of these lamps are made from the same glasses. Each lamp maker (U.S. and foreign) and each of the above lamps (with the exception of the 4000, 4002, 6014 and 6015) has a unique lens pattern. The name of the lamp marker is pressed into the lens of every lamp. The lamps that come as original equipment on the various passenger vehicles, where known, are as follows:

Current Suppliers of Orignial Equipment Headlamps

auto maker	*wagner*	*westinghouse*	*guide*	*g.e.*	*other*
AMC	100%[1]				
Chrysler	√	~ 25%			
Ford	√	~ 25%			
GMC			~ 100%		
British: Leland					[2]
French: Renault	√				
: Peugeot	√				
German: VW		~ 50%		~ 50%	
: BMW					Hella, #6014
: Opel			~ 100%		
Mercedes				√	
Italian: Fiat	√			√	Correlo
Japanese					[3]
Swedish: Volvo					[4]

[1] All AMC's business for last 5 years (through 1974) with Wagner

[2] British cars taking 7" twin-beams use Lucas lamps. Four-lamp British cars use U.S. lamps such as G.E.

[3] Japanese cars use Koito and Toshiba lamps which are probably made by Iwaki Glass Co., a subsidiary of Corning Glass Co.

[4] Volvo can come with G.E., Hella, Lucas or Westinghouse √6014 lamps.

Almost all replacement lamps sold in the U.S. are American made. In addition to having unique lens patterns, the name or trademark of each lamp marker is pressed into each lens and is stamped on the back of each reflector. Furthermore, "plunger" or "mould" numbers are stamped on both lens & reflector components. These numbers can be used to determine the approximate production date of a lamp. A coded production date is also stamped into the back of most lamps. The time lapses between production, lamp assembly and installation as original equipment are: about 2–6 weeks and about 0–2 months, respectively. Thus, if a headlamp is assumed to be original equipment, the dates that may be inferred from fragments obtained at the scene of a hit-and-run accident can be used to date the responsible vehicle. Such evidence could be used in tandem with paint evidence or visual observations.

The physical characteristics of a headlight fragment can also be used to identify the make and model of the lamp, and thence to infer the vehicle make and age. Furthermore, the comparison of such properties as RI, dispersion, chemical composition or density of an evidential fragment and lamp fragments obtained from a suspect vehicle can be used to individualize the evidence. In either case, it is imperative that the criminalist have extensive population statistics on headlamps so that the proper conclusions may be drawn from his investigations. Ojena and DeForest [OJ–2] have shown that RI (and therefore dispersion and density) vary considerably from manufacturer to manufacturer, from lamp to lamp and even within a given lamp. These variations could be due to stresses deliberately put on the lamps to temper them, compositional inhomogeneities, variations in thermal histories, or a combination of these. To some degree, however, the large ranges of RI, dispersion and density could actually work to the analyst's advantage. If these variations can be shown to be primarily due to stresses, then it is suggested that annealing could be used to reduce them.[28] This is a valid research project that could be undertaken in concert with an effort to obtain population statistics for these headlights. If it can be demonstrated that RI and dispersion measurements are valid means of classifying and/or individualizing glasses, (headlight or otherwise) then it would be highly desirable to: (1) make available to the forensic science community RI/dispersion standards with

[28] Dr. George Roche, Dept. of Police Science and Administration, Sacramento State College, private communication.

which they could calibrate their refractometers: (2) disseminate a standardized, sensitive technique for making such measurements.

Trace element analysis is another potentially useful technique for the individualization of glass. As with RI and density, however, the evaluation of such data requires some knowledge of the population statistics.

G.E. makes RI and density measurements on its headlamp glass. These measurements are only made, however, after the glass has been specially annealed. The American Glass Research Institute, Butler, Pa., claims to have made a substantial number of density measurements on lamp glasses, and they feel that substantial variations exist.

It is recommended that headlamp lenses be obtained from each glassmaker and their physical properties measured. Annealing should be used if it serves to reduce RI variability. Elemental composition and fluorescence characteristics should also be measured. The results of these researches will be the best guide as to how to proceed thereafter.

Aldermaston has a headlamp glass collection consisting of nearly 200 very high quality photographs, which may be available for about $400.

NBS has projects under way to 1) obtain RI and density population statistics for headlight glasses, 2) examine the utility of annealing the glass samples, 3) determine their trace element compositions and 4) develop RI standards.

There is a possibility of developing an SRC of molded plastic parking and turning signal lenses. These lenses, unlike those of headlights, are often unique for a given manufacturer and vehicle model. As such, their presence, even if only in the form of a fragment, can be of use in identifying the vehicle involved. In order to make such identification possible, two requirements must be met: (1) an SRC consisting of either actual specimens, or of photos, physical dimensions and characteristics must be developed; (2) a method of searching the SRC must be available. Wilkaan Fong et al. [FO–1] have developed such a search methodology. This project would not be an expensive one, but was not analyzed for merit since little was known about the need or caseload for these lenses. A survey of the crime labs, followed by a reevaluation of the utility of a turning and parking signal lens SRC, is in order.

Lowell Bradford (Private Communication) claims that most labs probably do not have sufficient caseloads to warrant their acquisition of individual SRCs of plastic lenses. The possible development of a single (or regional) plastic lens SRC is suggested.

The rate of occurrence of headlight filaments at crime scenes and their utility in headlight identification were not determined due to a lack of input. No recommendations regarding filament SRCs are, therefore, given. The condition of these sealed beam filaments after an accident can be used to infer their status (on or off) at the time of the accident. The physical process involved and suggested procedures are presented in [DO--1].

4.25 Paints, General

4.25.1 Background

This section deals with all types of paints except those used in the automotive industry, which are discussed in paragraph 4.26. Dyes, stains and inks are covered elsewhere.

The numbers of paint manufacturers, paint types and colors are quite large. Paint types include alkyd, enamel, epoxy, lacquer, latex, oil, styrene, water soluble and vinyl. Each paint is composed of many constituents, including pigments, binders, vehicles, solvents, thinners, extenders, fillers, fungicides, etc. A reference describing the various paint types and constituents is the book by Crown [CR1]. The frequent absence of good quality control is complicated by haphazard alterations in formulations and/or ingredient suppliers. K. B. Snow et al. [SN–1] examined about 300 paint samples from major U.S. manufacturers, using NAA for both qualitative and quantitative analysis. Quantitative agreement between samples of the same paint, but of different lots was attained in only 21 percent of the red, 33 percent of the white, 14 percent of the blue and 24 percent of the green paints examined. Even if identification of a paint type and manufacturer were possible, the utility of such information, given the absence of population statistics and wide and undefined distribution patterns, is minimal. The only really useful paint analysis is the comparison of source and suspect materials (e.g., a comparison of paint obtained from a window sill and from a crowbar).

In accordance with the above factors and the very low rating shown in table 3, a general paint SRC is not recommended for further consideration.

Methods for the accurate analysis of dried paint should be perfected so as to facilitate laboratory comparisons. Among methods currently used, or under investigation, are NAA [AD–2], P–GC [LE–2, P325], electron microprobe [LE–1, p 347], IR [PA–2], and emission spectrometry. NAA and spectrometric analysis techniques are being investigated under the aegis of the AOAC, according to Douglas Park of that organization. [LE–1, p 327] gives a summary of present research into paint identification methodology. Spectrometric methods are suitable both for paint identification and individualization. Fred Paul et al. [PA–2] describes an inexpensive method of converting a conventional Beckman DK 2A spectrophotometer, with reflectance measuring attachment, so as to be able to handle small paint fragments. Aldermaston has, and continues to build up, a data bank of paint programs and population statistics [CU–2]. Evidence in the form of a comparison of paint chips from a suspect's clothing, etc., with paint presumed to have been disturbed during the commission of a crime, is often used in court. In this regard, E. F. Pearson et al. [PE–1] surveyed the outer clothing of a group of people (non-suspects) to determine paint-chip ambient conditions (i.e., background levels). This is an admirable project and should remove a possible source of errors.

4.26 Paints, Auto

See also Section 4.25.

4.26.1 Background

Much of the discussion in 4.25 applies to 4.26. Some differences exist and are described below. A principal difference is the smaller number of unique auto paint elements. Still, the number of auto paints involved is quite large. For example, G.M. and Ford offered 40 or more color choices in 1973.[29]

Before each model year, the auto manufactrer stylists decide on that year's colors and make up "color standards." These color standards are then submitted to the various paint manufacturers for bids. Included among these manufacturers are DuPont, PPG (Ditzler), Ford and five or six others. These companies are required to deliver a paint of specified color and satisfactory working and wearing characteristics. There are over 100 automobile production plants in the U.S., and each may select a different paint source. A given auto plant may use more than one paint supplier for a given color, and may vary its paint suppliers during a model year. The paint manufacturer is not obliged to use a specific formula, and thus may vary his paint composition as basic ingredient costs or availabilities change.[30] Each plant is also somewhat autonomous in how it applies its paint, so that solvents, sprayers, drying times and temperatures may vary from plant to plant. One plant may do spot touch-ups while another may touch-up by panel.

In recent years, according to new vehicles registrations, about ½ the cars purchased on the West Coast have been of foreign origin. Thus, a whole new set of paints must be convoluted into the picture. Furthermore, touch-up and refinishing paints can differ in composition, as well as in color, from the original paints. This is due in part to the fact that the original coat may be baked on at over 200°C while a touch-up or refinish coat will be put on at a lower temperature. DuPont plants manufacturing auto paints include the following:

PLANT LOCATION	ORIGINAL AUTO PAINTS	REFINISHING/TOUCH-UP PAINTS
Detroit, Mich.	√	
Flint, Mich.	√	√

[29] According to Mr. Paul Britt of Dupont Automotive Color Lab, Troy, Michigan, Private Communication.

[30] However, since a paint manufacturer is obliged to match the spectral characteristics of a "color standard," paint composition is not generally altered substantially.

PLANT LOCATION	ORIGINAL AUTO PAINTS	REFINISHING/TOUCH-UP PAINTS
Fort Madison, Iowa	√	
Harlan, N.J.	√	√
Moberly, Missouri	√	√
Philadelphia, Penna.	√	√
South San Francisco, Calif.	√	√
Toledo, Ohio	√	
Tucker, Ga.	√	

Finally, we have to consider the effects due to aging, solarization, weathering, leaching, washing and waxing, each of which can alter the color and/or chemical composition of the exterior finish.

Even with all these variants and vagaries, many criminalists contacted claimed that the FBI can not only identify the make and model of a car based on paint chip analysis, but frequently the plant at which the car was manufactured.[31] In this regard, it should be noted that the FBI receives paint panels from each auto manufacturer and adds them to their National Automotive Paint File.

In many cases, it is not possible to identify the car model or make, since the same paint color may be used for more than one car model. Thus, AMC offers several identical colors for their 1973 Ambassador, Matador, Hornet, Gremlin and Javelin cars. Furthermore, a large company like GM may use the same color paint for more than one car "make" (e.g., 1973 Cadillac, Buick, Oldsmobile and Pontiac offer several identical colors). A similar problem is the use of the same color for several production years. These practices, which occur throughout the industry, can modify the interpretation of a color match to the point where the vehicle (make, model and production year) population inferred is so large as to be of little use in suspect development.

As mentioned in paragraph 4.25, Aldermaston, using P-GC, has been building up a major bank of analytical data on paints. It is not clear from [CU–2], however, if auto paints are involved. Toronto, Chicago, and Plymouth, Mich., labs also have paint panel SRCs.

In order to determine what form of vehicle exterior paint SCR could assist the crime laboratories in vehicle make, model and year identification, the following questions must be answered:

a. How consistent are the compositions and colors of these paints? If variations among one or both are unduly large and lead to errors or anomalous inferences, then that means of identification must either be excluded or given a low profile. If both aspects of these paints prove consistent (with time, plant, etc.), then both may be viable.

b. How unique are the inferences that could result from use of such an SRC (composition or color)? If many of the inferred subpopulations, though definitive, are still quite large, then the utility of this SRC is lost. Examination of multiple paint facets might improve this dilemma (i.e., an additional degree of definition may be obtained by use of multiple tests, e.g., color, paint type, layer thickness, composition, etc.). In any case, each SRC element (whether by paint or composition) should cross reference all the vehicle makes, models, and years that can be implied by the match. Where possible, secondary means of differentiation should be given.

c. What form should the SRC elements take? If paint composition is to be the means of identification, then one can use actual paint panels (actual paint sprayed on aluminum or steel panels) of a size (>2 cm^2) large enough to permit removal of sufficient material (say by scraping or submission to emission spectrometry) for several analyses.

If paint color is found to be the best method of identification, then two possibilities exist: the paint panels as described above, or paper color tabs (see for example, [DI–1 and DU–1]). These books are thorough, but for optimum use, should be arranged by color and not by manufacturer.

The use of actual paint panels has the advantages of producing spectral standards as well as compositional standards. Unfortunately, the use of such panels will probably make the SRC both bulkier and more expensive. Large paint panels will have to be obtained from the various auto

[31] Charles Hammer (Georgetown Univ.) claims (Private Communication) that, for the last five years, auto paint manufacturers have been tagging their paints voluntarily and sending related composition and manufacturing data to the FBI. If this is so, it represents a breakthrough for the advocates of tagging (see paragraph 5.2).

manufacturers, from which the vehicle paint SRC developer will have to cut small chips. At least 300 to 500 such metal chips should be produced for each unique color and/or compositional variant.

The advantages of a paper tab SRC are its compactness and relative cheapness. Unfortunately, these paper tabs would be of essentially no use in compositional analysis. Futhermore, due to differences in composition and/or method of application from the standard vehicle paints, metameric effects may result when light source, viewing angle or visual response are varied. If a sufficient loss in color matching sensitivity is generated by such metameric effects (or by poor quality control of the paper tabs), then one might opt for paint panels, even if they are to be used only for color matching.

For a color SRC, variations in finish (glossy, semigloss, flat, matte, fluorescent, metallic, etc.) must all be assumed to produce unique SRC elements unless it can be otherwise demonstrated.

d. When a principal means of identification is selected (composition or color), then the method of ordering the file must be decided upon. For a composition SRC, it could be by percent of the elements or position of the largest spectral peaks, depending on whether the means of analysis is visible spectrometry, emission spectrometry, P-GC, NAA, etc. For a color oriented SRC, the possible ordering systems include Munsell, Tristimulus, ISCC-NBS [KE–2], etc. There are two facets to the ordering problem, the first being the means by which the developer orders the file, and the second being the means by which the user enters the file, based upon his analysis of the unknown. The developer could use the most advanced and sensitive instrumental techniques to order his file, but he must be aware of the limitations of the crime laboratory. That is, the means by which the vehicle paint SRC is ordered is unlimited, but the means at the disposal of the criminalist to enter the file will doutblessly be quite limited, Indeed, the criminalist will prefer the simplest method that will give him at least the minimum requisite sensitivity. For this reason, if a color oriented SRC is viable and if a visual means of entering the file and making color match is at all possible, it is to be preferred over another, albeit workable, alternative.

Note that the ASTM has set up standard methods (designations D1729–69 and D2244–68, respectively) for visual and instrumental methods of evaluating color differences for opaque materials.

e. The metallic colors represent a real challenge to the viability of any auto paint SRC. These colors represent about 70% of the unique colors available as initial equipment for U.S. made passenger vehicles over the past 4 years, and this percentage is probably increasing. These metallic colors are quite difficult to classify using existing solid color reference files. Furthermore, it is not possible, at present, to simulate these metallic colors on paper backing to the degree that the solid colors can be duplicated. An auto paint SRC will almost, of necessity, require the development of a metallic equivalent to the Munsell, ISCC-NBS, or other existing color standards.

Auto individualization generally involves the comparison of an unknown and suspect sample color, layer morphology, etc. For such analyses, SRCs are not required.

Since hit-and-run accidents almost always involve the transfer of some paint, their rates of occurrence and the consequent need for methods of auto identification rank high [BR–12, PA–2].

Other means by which autos can be identified are their styling and silhouette patterns. These, however, would be of use to detectives and not crime labs, per se.

4.26.2 Recommendations

It is recommended that further evaluation be made of the feasibility and utility of an auto paint color SRC. Although the rating obtained by this category in the mathematical analysis is borderline, it is felt that additional data may alter this value substantially. That is, the need for a method of vehicle identification has been observed, but it remains to be seen if a vehicle color SRC is viable.

4.26.2.1 Basic SRC Specifications

As envisaged, the SRC would consist of color representations, either on paper, as found in the various manufacturers' display books, or actual paint panels, arranged according to some standard color system. This arrangement will have to take the following factors into consideration:

a. The realities of the crime laboratories—that is what methods of color assignment are available at present (probably visual and spectrophotometric).

b. The color system selected will have to minimize the number of unique vehicle colors that fall within the smallest "bin" of that system.

A method of entering this file with an unknown must also be devised. Alternate methods of differentiation should be included in the data accompanying each element. For example, the type of paint (lacquer, enamel, alkyd, etc.,); number of coats; etc., should be presented in addition to color tabs to make vehicle differentiation possible when color matches occur within the established color system.

If spectrophotometry or other instrumental methods of color coding are used then, in the spectral regions of low element density, visual color coding and search options should be made possible.

4.26.2.2 SRC Sources

The auto and paint manufacturers.

4.26.2.3 Implementation Factors

The cost to a purchaser of the final auto paint SRC would depend on its form, but will probably be $100-200. Of course, a vehicle paint SRC will have to be updated annually, and each lab desiring such a service would contract for it at some fee.

4.26.2.4 User Factors

Although no restrictions are envisaged for the distribution of a vehicle paint SRC, all potential users of such a file should have their vision tested for color-blindness. Colorblindness of varying degrees exists in about 9 percent of the male population, and many people are not aware of the existence of this defect in their vision.

4.26.2.5 Research Requirements

As described, substantial research must be performed to determine:

a) The optimal form of the SRC. That is, a selection between color representations on paper and actual paint panels must first be made. Next, the color coding system that permits optimal element separation (maximum separation with minimum number of "bins") must be determined.

b) The viability of this SRC form must then be considered and a decision made as to whether to proceed.

c) The associated data that should be included with each SRC element, to insure differentiation where differences exist, must be developed.

d) If vehicle identification by visual or spectrophotometric methods is not found to be feasible, then chemical analysis methods should be investigated.

Actual visual and instrumental analyses of both color representations and paint panels will be required for parts a) through c) above.

4.27 Shoe, Sneaker Prints

4.27.1 Background

As can be seen from appendix C, "tracks" rank 16th of 23 categories in rate of occurrence at crime scenes. Although this category includes other types of tracks (e.g., tire, etc.), it can be assumed that "tracks" refer principally to shoe prints. Shoe prints (marks) are useful both for identification of the type of shoe worn, and for individualization (i.e., comparison of a plaster cast or photo with the equivalent made from a suspect's shoe). The role of the "foot mark" examiner is described in [FA–2]. There was some desire expressed for a shoe print SRC among those criminalists surveyed. Again, the question must be asked—how useful would such a file be? The numbers of shoe manufacturers and styles are quite large, and a great many shoes are made abroad. A disproportionately large number of criminals use sneakers (U.S. and foreign) and inexpensive (often foreign) shoes. It would be quite difficult to keep track of all the domestic and foreign shoe and sneaker prints, or to catalog them for easy identification. Furthermore, the utility of an identification will generally be nil since the distribution patterns of inexpensive shoes are doubtlessly inextricable. It is recommended, therefore, not to further consider any SRC or research with regards to shoe/sneaker prints. Kingston (appendix A) and Brunelle (appendix B) rank shoe prints 23rd of 24 categories, and not-at-all, respectively.

4.28 Tire Tread Patterns

4.28.1 Background

The uses of tire imprints/marks are fivefold [GR–1]:

a. Based on a tread imprint/mark, the tire make and model (or makes and models) can sometimes be ascertained.

b. Based on a tread imprint/mark, a tire can sometimes be individualized.

c. Based on track width (spacing) and/or tire make and model, the make and model of the car can sometimes be inferred.

d. Based on imprint depth, the age or condition of a tire (and thus of the car associated with the tire) may be inferred.

e. Turning radius can also be used to infer vehicle model.

To identify a tire make/model from a tread pattern, a criminalist will often refer to the following annual publications, all published by "Tire Guide" [32]:

name of publication	*contents*	*reference*	*price*
Tread Design Guide	Illustrations and data on over 3,000 passenger car, truck, motorcycle, etc. tires and retreads covering over 150 tire brands.	[TI–1]	$6.00
Tire Guide	Lists, for all passenger car models from 1965 through 1974, and for light trucks and motorcycles from 1971-1974, the make, year, and sizes of standard and optional tires. Complete passenger tire line charts are also given.	[TI–2]	$4.00
Who Makes It? and Where?	Lists all state and local tire manufacturers and distributors. Where to write for "hard to find" information. Names and addresses of major and private label brand companies. A comprehensive alphabetical listing by brand of almost every major and private brand tire made. DOT code chart identifying manufacturer of every tire (domestic and foreign) sold in the U.S.	[TI–3]	$1.00

The "Parking Dimensions of Automobiles," which gives tire spacings for the various auto makes and models, is used by many crime labs.

These publications, and particularly the "Tread Design Guide," can assist an investigator in determining the brand (or set of similar-tread brands) responsible for a tire print. The "Guide" does, however, suffer the following drawbacks for criminalists:

a) The illustrations given (< 3,000) are of actual tires and not of the prints they make. The investigator must mentally convert each illustration to an equivalent tire print (or vice versa) in order to make a match. Since many patterns are quite similar, "match making" is very tedious.

b) Since the illustrations are not ordered according to a morphological or measurement based system, extensive scanning may be required to make a match. Since there can be no assurance that a match, once found, is unique, all illustrations must be scanned if all possible matches are to be made.

c) Unless the investigator is fortunate enough to obtain a cast of a deep impression, or a print or cast of a tire with bald spots, the age or condition of the tire cannot be estimated by use of the illustrations.

[32] A Bennet Garfield publication, 2119 Route 110, Farmingdale, N.Y 11735.

Since tire prints frequently are found in association with criminal acts, appendix C ranks "tracks" sixth of 23 "physical object categories," and since both tire and auto identification can be quite helpful in suspect development, an SRC that would assist in these endeavors would be of great benefit to both criminalists and detectives.

Although there are about 120 tire brands, there are only about 15 major U.S. and 7-8 major foreign tire manufacturers whose products appear on the American market. The difference (approximately 100) is due to distributors (e.g., Pep Boys, Sears, Wards, Western Auto, etc.) who purchase tires from major manufacturers and add their own brand names before marketing them. Thus, one tread pattern may be common to many brands. For example, Armstrong sells tires to about 50 such companies. A few firms, however, supply their own molds to the manufacturer. The number of unique tread patterns is on the order of 500.

The FBI has a reference collection called the "Tire Tread File" which associates tire brand with tread patterns. Many tire manufacturers take their own tread patterns for advertising purposes. There are a few companies that test tires and prepare pictures and prints for advertising purposes. The "Tire Guide" is one of these, and another is Smithers Laboratories, a division of Smithers Scientific Services, Inc., Akron, Ohio. Smithers does testing of all major and many minor brands. In addition to recording the structural data, they take a "footprint" of each tire examined (fill the tire to the correct pressure and load it, obtaining an oval, static print). They send a copy of each print they make to the FBI, and have developed an extensive file of their own, going back to 1928.

4.28.2 Recommendations

In accordance with the high ranking (first) obtained for this category (appendix G), and the needs expressed by most criminalists surveyed, it is strongly recommended that further consideration be given to the development of a tire print SRC. The absence of a tire mark category from appendices A and B may not be significant, and may just represent a bias of the population surveyed.

4.28.2.1 Basic SRC Specifications

The SRC should consist of illustrations of each unique tire "footprint." To be comprehensive, the SRC should go back at least 3 years. For ease in updating, the data elements should be bound in looseleaf form. Each illustration should be large, perhaps 1:1. Prints should be taken at standard operating pressures and loads. Since the sidewall patterns may also be useful in tire identification, these should also be included in the illustration. Each print should be accompanied by manufacturing data, identification of all tire brands that have that print, the makes and models for which each tire is standard or optional equipment, and an illustration of the tire similar to those found in the "Tread Design Guide."

The ordering of the SRC elements should be such as to eliminate the need to scan the entire file. For instance snow tires could be in a separate category. A morphological arrangement based on the tread dimensions could be useful.

Foreign, domestic, passenger, motorcycle, and truck tires should be included. Bus, tractor, and other unusual type tires should only be included if there is a demand for them by the law enforcement community.

4.28.2.2 SRC Sources

Tires and technical data will come from the manufacturers, as may some prints. Smithers should be able to make their existing file of prints available. Much data can also be obtained from the publications described in paragraph 4.28.1. Information on standard and optional tire brands can come from the publications and auto producers.

4.28.2.3 Implementation Factors

Much data collation and/or certification is required. Search and filing systems must also be developed. Where prints are not available or are unsatisfactory, tires will have to be obtained and prints made. These combined projects should require, as a rough estimate, about one man-year. Money could be saved by referencing the elements in the file to pages in the various publications described in 4.28.1, but then some of the advantages of this file would be lost.

Updating should be done yearly, as new tires are introduced and/or as auto manufacturers change tire brands. Users should be able to contract for this updating service on an annual basis.

The cost of the basic SRC should range from $50-$100 and the updating contract could run about $12-$15/year.

It would be helpful if the SRC included data on how tire patterns changed with wear. Unfortunately, this could be quite costly to the overall project. Needed, would be illustrations of those parts of the tire prints that most readily show the degree of wear, and quantification of these pattern changes.

4.28.2.4 Users

There does not appear to be any reason for restricting distribution of this SRC; however, the tire and auto manufacturers may be unwilling to transmit data unless distribution is restricted to law enforcement officials.

4.28.2.5 Research Requirements

The only research required is the development of a filing and search system. The remaining tasks are of a data collection and collation nature. Another research project, that of quantifying morphological tread changes with tire wear or miles driven, is not recommended at this time.

4.29 Tire Tread Composition

4.29.1 Background

During a skid, tires can deposit a significant amount of tread material, possibly enough for a chemical analysis. Besides the analyses made by the various tire manufacturers, a private company, Smithers Scientific Services, Inc., Akron, Ohio, has served as an independent tire analyst and tester for a major portion of the industry. They perform both instrumental and wet chemical analysis of tires. They also do forensic testing, and give court testimony where necessary. Based on accumulated data, they can sometimes identify the manufacturer. As mentioned in paragraph 4.28, they also make tread patterns and their reference file on such patterns is of assistance in such identifications.

P–GC may offer hope as a new method of tire analysis. Still, development of a SRC cannot be recommended unless it can be shown that:

a) Most tire manufacturers have unique and differentiable products.

b) Enough material is deposited during a skid for quantitative analysis.

c) Quality controls of tire manufacturers are such as to confine the composition ranges.

d) Changes in composition, due to formulation changes, aging, temporal variations, etc., are not such as to vitiate standards.

It is felt that the caseload is not sufficient to warrant the large effort that would be required to answer these questions. This is in accord with the low ranking obtained by this FSM in the analysis of appendix G.

4.30 Safe Insulations

4.30.1 Background

Safe construction materials include iron, lead (often in the form of lead shot for weight), asbestos (for fire proofing) and diatomaceous earth (filler, fireproofing).

Kingston's and Brunelle's surveys (appendices A and B) rank safe insulation 10th of 24, and 13th of 16 classes of materials in need of investigation, respectively.

Due to a dearth of inputs to this category from all project sources of information, no SRC recommendations are made for these materials at this time.

4.31 Explosives

4.31.1 Background

Very little input was obtained with regards to explosives. Generally, only a few Federal agencies are responsible for investigating crimes involving the use of explosives. In particular, the ATF (within this group; Drs. Elliot Byall and Charles Midkiff) handles the analysis of residues, etc. The primary methods of analyzing residual materials are microscopy [WA–1], XRD, NMR, GLC, TLC [KE–1], DTA [LE–2, p359] and IR emission spectroscopy.

Dr. R. D. Braddorff of Hercules, Inc.,[33] is the chairman of the Technical Committee of the Institute of Makers of Explosives and may be in a position to give technical guidance.

The ATF has a modest SRC consisting of about 40 commercial explosive compounds. Although fuses are sometimes used, timing or other electro-mechanical devices are more common.

Since explosives are only handled by a very few Federal agencies, it is felt that any SRC should proceed with their backing.

4.32 Weapons, Firearms

4.32.1 Background

In addition to the potential for individualization of a firearm, based on comparison microscopy (ordinary or SEM), identification (make and model) is also possible. When a firearm is discharged, tell-tale marks are left, both on the cartridge case and on the bullet. Each weapon has a distinct firing pin and rifling configuration. In the past, crime labs have used standard references such as [BA–2, MA–1 (3 vols.) and WH–2]. H. P. White [WH–2] has published a set of cards containing the rifling characteristics of common firearms. Although some reference books have been updated, current, comprehensive card file SRC has been requested by many laboratories. Such an SRC tied for 3rd in the mathematical analysis. The principal reservations are the great expense that would probably be required to fire bullets from the very large number of manufactured firearms, and their certification and analysis. Kingston's survey (appendix A) ranked "bullets" and "firearms" 13th and 24th respectively, of 24 categories. Brunelle's survey (appendix B) contained no "firearms" listing but did rank "bullets" 11th of 16 categories.

4.32.2 Recommendations

If, through free access to large existing collections, the cost of such a project can be minimized, then it should be given full consideration.

4.32.2.1 Basic SRC Specifications

A firearms SRC should be in the form of an updateable card file. Such a file would contain the following data:

a) Name of firearm manufacturer, model name and/or number, caliber, photo or drawing, dimensions, dates of production and serial number range.

b) Number of lands.

c) Width of lands as they appear on the bullets (not on the firearm).

d) Direction and amount of twist.

e) Type and position of firing pin mark. A drawing giving dimensions would suffice.

f) Other caliber bullets that the gun can chamber and fire.

Most literature to date gives the manufacturer's specifications for land widths; however, the criminalist only gets to see the markings on a bullet. Manufacturing tolerances may result in variations in rifling characteristics—this is true both of domestic and foreign firearms. Therefore, land width ranges are needed.

One method of producing such an SRC would be the development of a firearms museum

[33]Address: 910 Market St., Wilmington, Del. 19899.

containing one or more of each make and model of weapon. This would be possible if holders of major collections (almost every police department has a "gun collection") would be willing to contribute to this central SRC. Alternatively, the major gun collectors could be requested to test fire each of their firearms with standard, pre-selected bullets, free of existing scratches or markings. Both jacketed and lead bullets should be fired where a weapon can take both. The weapons must be checked to insure they are not make-shift or significantly altered from their manufactured configuration.

Where more than one specimen of a particular firearm make and model is available, a range of land width data will result. These could be correlated with amount of usage and serial number.

Foreign as well as domestic firearms must be included and the file should be updated annually, or as new models come on the market. All model variations which can produce changes in the rifling marks or firing pin impression must be included in the SRC, as must modifications which result in an altered appearance of the firearm.

Weapons other than firearms are of limited interest and were not found to require SRC consideration.

4.32.2.2 SRC Sources

Almost every crime laboratory and/or police department has a firearms collection. The FBI and ATF, in particular, have extensive collections. Serial number ranges, dates of production, etc, will have to be obtained from the various manufacturers. The Chicago Police Department may have substantial firearms data.

4.32.2.3 Implementation Factors

B. D. Munhall and H. P. White may be in the process of developing relevant data, and certainly could contribute to such a project. The FBI, ATF, or Smithsonian might be amenable to housing a firearm collection, but the collection should be available for special requests by accredited officials. The card file SRC would be a one-time purchase, supplemented by a subscription to keep the file current. Cost of the card file should not be prohibitive, yet high enough to recoup some of the development and printing expenses—say \$250–\$300. The ordering of such a file could follow conventional open bullet file systems (i.e., by caliber, direction of twist, number of lands, etc.).

4.32.2.4 User Factors

Since such an SRC has no apparent utility to the general public, it is recommended that its sale be restricted to accredited law officials and/or their respective agencies. The firearm collection, on the other hand, could be open to public inspection and this might help recover some of the development costs if a viewing fee were charged.

4.32.2.5 Research Requirements

Manufacturing data, the location of rarer model firearms, etc., will all have to be researched by the developer. Fortunately, much firearm data are in print.

4.33 Ammunition, Residues

4.33.1 Background

Some of the discussion of paragraph 4.32 is relevent here. In 4.32, however, ammunition was of interest only as it could relate back to the firearm make and model. This section is concerned with the ammunition, per se. Gunshot residues are also included here.

Just as the markings on a spent bullet or case can indicate the make of the firearm from which it was fired, a bullet and/or cartridge case can tell you the make of the ammunition. In fact, many cases have a manufacturer's imprint stamped on their bases. Due to broad distribution patterns, the utility of such knowledge is minimal, and there appears to be little demand (or need) for an ammunition SRC.

As for residues, an optimum method of recovering them from the hands of the shooter must be developed and set into a standard. Michael Hoffman of ATF has recently become the Associate Referee of the AOAC's activities in gunshot residue analysis.

Supposedly, the discharge of a weapon generates free radicals from the gunpowder. These radicals have long halflives, on the order of hours or days. Some investigation as to their potential for residue identification should be explored. The possibility of using such residues to estimate time since firing should also be considered. A good review of the use of NAA in residue detection is that by M. Pro [PR–2].

This is an exceptional case where, although the mathematical analysis indicates a marginal acceptability for further consideration of this FSM class, no such recommendation is being made.

4.34 Accelerants

4.34.1 Background

In arson, an "accelerant" is often used to insure or hasten conflagration. Approximately 90 percent of the time, these accelerants are petroleum distillates [MI–1] such as naphtha, kerosene, fuel oil, varsol, gasoline, charcoal lighter fluid, etc. All of these liquids can be readily obtained from numerous sources. Often, it is sufficient just to determine that accelerant residue is present and, therefore, that arson may be the cause of the fire. For presentation in court, the generic name of the accelerant should be determined. Any further information that is obtainable, such as brand of gasoline, can assist in suspect development as well as provide additional evidential impact.

Gasoline is a frequently used accelerant. All leaded gasolines, by law, must be colored. In addition, most gasoline brands contain "additive packages." These are unique for each company. Several factors, unfortunately, modify the utility of these additives in identification. Among these factors are: (1) the degradation and volatilization of additives due to the conflagration heat, or simply as a function of time, (2) poor quality control, (3) mixing of gasoline brands by the gas stations (especially the non-affiliated stations that purchase from the lowest priced supplier), (4) change in gasoline constitution. Many large gasoline producers vary their additives with time of year, as a function of region of country and by grade.

Some criminalists, such as Charles Midkiff (ATF), are developing spectra and other data on accelerants. Others are looking into the effects of thermal history on the degradation product populations. Common methods of analysis involve (after sampling for the non-native substances, say, by steam distillation or head space sampling), GC–FI and GC–TC [CH–2], boiling range determination, GLC [MI–1], and IR spectrophotometry. GC–MS may also prove useful [LE–1, p 281]. A good overview and bibliography of accelerant residue analysis is given in [LE–1, p337]. The referee for this project is Charles Midkiff.

Much further research into sampling and analysis is needed. Detection of accelerants and/or additives should be the goals of such researches. In this regard. the AOAC has recommended research into the "identification of flammable fluids by GLC" [BR–14]. The referee for this project is Charles Midkiff.

In accord with the analysis in appendix G, the development of an SRC consisting of each potential accelerant is not considered worthwhile at this time. Spectra and physical property data, while of significance, depend on the purity and source of the accelerant, as well as its thermal history, sampling and analysis procedures. The last two must be investigated. Many labs have pilot programs in this area (especially ATF), and a more orderly defined program would be useful.

Appendices A and B appear contradictory in terms of the level of interest in the study of accelerants. That is, while those surveyed by Kingston rated accelerants ("petroleum products") 12th of 24 categories, Burnelle's list of 16 materials requiring further study does not even contain a related listing.

5. ADDITIONAL FINDINGS

5.1 The Tagging of Manufactured Goods of Forensic Value

As described throughout Section 4, many FSMs are of limited value due to the variability imparted to them during manufacturing. Even where subclass variations may be large, there often exist several alternative methods of identification. Some of these are:

a) Examine those quantities that do not have large uncertainties. Unfortunately, this frequently involves more intricate, expensive and time consuming analyses.

b) Examine several (albeit highly variable) characteristics in tandem. The interpretation of each analysis may not be statistically meaningful, but the cumulative result can be significant. An example is elemental composition analysis. Many elements may only be poorly determined, but the overall analysis may still be definitive. This approach is valid and is used to identify such materials as soil, glass, and paints. However, these analyses (both instrumental and mathematical) are quite time consuming and often require expensive instrumentation and a high degree of scientific sophistication.

c) The development of an extensive data base consisting of population statistics, manufacturing and distribution data, and background levels. Data base development may be required for alternatives a), b), and d) also.

d) Tagging. To each distinct material subclass is added some quantity, or quality which permits the criminalist to readily identify it. Tagging may involve the addition of a chemical or elemental constituent to a product; this process is also known as "spiking." The spiking of such forensic materials as glass, paint, gunpowder and explosives has long been desired by many criminalists and would certainly ease their burdens and increase their efficiency and capabilities. For the most part, spiking has been rejected by the various industries as adding to the cost of the products spiked and requiring quality controls they may not presently exercise. As mentioned in paragraph 4.26, however, several auto paint manufacturers may presently be spiking their products for the FBI.

Tagging may also take the form of altering, labeling, or varying the appearance of a product so as to distinguish it either from another product, or as a function of time. Some examples include the labeling and marking of solid drug dosages, watermarks on paper, alterations of typeface (see paragraph 4.15), and markings on cartridge cases.

Where a product has an obvious potential for injury or destruction (firearms, ammunition, explosives, automobiles), and where tagging such products would significantly aid the criminalist in their identification, the related industries should be requested (or compelled) to take appropriate actions. In some cases, legislation may be required. Manufacturers of imported goods of the same nature should also be required to tag their products.

5.2 A Comparison Microscope with Slide-Handling Capability

Several recommendations given in Section 4 involve slide SRCs. The majority of these slide SRCs are of microscopic objects and are to be used to classify forensic materials. A comparison microscope that would take an unknown sample on one side and a slide SRC on the other would appear to merit consideration. If the SRC consists of a substantial number of elements, then a roll of film could be used in place of the slides. Such an instrument (accepting either slides or film on one side) does not appear to exist at present, but may be feasible and practical. The lack of a third dimension (depth) of standard slides or film does pose a serious problem. Dr. Saylor of NBS has indicated the possibility of developing "3-D" slides. Dr. James Benford of Bausch & Lomb should be contacted in this regard. Possible methods of obtaining 3-D slides include holography, and multiple-layered slides (or film).

6. SUMMARY OF RESULTS

The primary objective of this project was to investigate the standard reference collection needs of the crime laboratories and, based on available information, make recommendations as to: needed collections, optimal forms, scopes, potential SRC developers, user restrictions, and areas of study required adjunct or preliminary to recommended projects. Information sources included criminalists, the forensic science literature, and representatives of both the manufacturing and testing laboratory communities.

Unfortunately, the forensic science community has become wary of those requesting information in exchange for vague promises of improving their lot. Nevertheless, most criminalists contacted personally or by telephone gaver willingly of their time. Contacts made with representatives of the industrial and technological communities were also very profitable.

An analysis of the information and opinions gathered during the course fo this project indicates the following problem areas in forensic science:

a) The level of criminalists' research in the U.S. appears to be relatively low when compared to, say, its counterpart effort in the U.K., and is almost exclusively concentrated in drug-oriented studies.

b) The degree of standardization or uniformity of techniques, instrumentation, etc., among the 200 or more crime laboratories throughout the U.S. appears to be very low.

c) The scope of forensic science is very broad, and articles pertinent to it are scattered through dozens of journals covering numerous disciplines. The absence of a continuous survey of pertinent articles/books (such as "Current Contents") has made it difficult for the criminalist to keep up with the literature.

d) Insufficient communication between criminalists (as a group) and technology, industry and the other sciences has frequently left the criminalist without the basic support he must have from these communities. That is, since these communities do not get to hear of the needs of forensic science; they do not move to meet them. In turn, the criminalist does not rapidly learn of the advances made by these various communities, and so his techniques and instrumentation are generally not the most advanced.

e) At this time, when crime lab techniques are trailing behind those of the basic disciplines they relate to, the courts are lagging behind the labs in terms of types of evidence they will admit. A case in point here is blood-group analysis.

f) A disturbing facet of forensic analysis is the apparent dearth of manufacturing data and population statistics regarding forensic materials. In many cases, it is inconceivable that valid conclusions can be drawn from analyses of such materials without the benefit of such information.

g) Also disquieting is the infrequency with which crime scenes are searched, or physical evidence retrieved or analyzed. A less than one percent rate of crime investigation is commonly quoted. To compound this sin of omission, more than 60 percent of forensic analyses are drug or alcohol oriented; that is, most analyses are directed at solving, essentially, victimless crimes.

h) Most courts demand that the criminalist personally present the results of his forensic analysis in court. The criminalist typically loses at least one day in five to courtroom appearances.

i) A major problem area is the extreme variability of many manufactured goods due, in part, to quality control variations, changes in raw material sources, formulations, techniques, etc. Such variability severely limits the utility of some SRCs for the identification of forensic materials. Diffuse distribution paths also tend to limit the interpretation that can be placed on forensic analyses.

j) In a few cases, modern technology has resulted in the development of highly uniform goods which limit the potential for individualizing them. A case in point is modern type faces. Therefore, the criminalist faces major problems which arise from standardization, improved quality control, etc., (as from the lack of them; as indicated in problem area i).

k) Many technologies are changing rapidly and the associated reference collections, data files, and population statistics must be kept current if they are to maintain their utility.

With regards to SRCs, the following observations are believed to be noteworthy:

a) Tagging of manufactured goods of forensic value could remove some of the criminalist's burden and improve the reliability of his results. "Tagging" is discussed in paragraph 5.1.

b) The scope of forensic science, and hence this study, is so broad that an in-depth evaluation of each FSM class was impossible. Those FSM classes eliminated from table 1, and those classes rejected from table 2, would probably have suffered the same fate no matter what time had been devoted to them. Those FSM classes either recommended for further consideration, or of an indeterminate nature (see table 3) could not receive adequate review in some cases. Thus, the recommendations given may not, in some cases, be sufficiently explicit or detailed, or truly representative of all existing needs. In such cases, more groundwork may be desirable before serious funding of recommended projects is initiated.

c) Relatively few of the recommendations of Section 4 involve the development of actual specimen SRCs. More than 50 percent of the recommendations involved the development of data files (physical properties, manufacturing data, etc.). Many materials require population statistics data either as, or in addition to, the recommended SRC. Several recommendations include photomicrographs but, surprisingly, only a few recommendations for the development of physical or chemical standards are made. Centralized SRCs (e.g., museumed FSM collections) appear to have but limited utility to those criminalists surveyed.

APPENDIX A

Kingston's Survey/Results

The following questionnaire was distributed to members of the ASTM and Forensic Science communities under the aegis of the ASTM:

1. Data derived from comparative examinations of evidential materials must first be evaluated before their significance (e.g., as indicators of common origin) or legal relevancy can be determined. How important is the need to improve these evaluations? (Check one)

   No need ________
   Some need ________
   Substantial need ________
   Critical need ________

2. For which specific evidential materials is the need most pressing for improved data evaluation? Please list only those materials that you feel are relatively important as evidence and that occur with reasonable frequency. (List in order of importance).

   1.
   2.
   3.
   4.
   5.

3. Would you or your laboratory be able to participate in the development of "standard" analytical procedures and/or collection of data concerning the materials listed in Question #2? (A "Yes" answer does not commit you to do this, but indicates your interest and willingness if conditions permit).

   No________
   Yes________ (If Yes, which materials)

4. Are there any other general needs, and related specific needs, that you would like to bring to the attention of the Criminalistics Sub-Committee?

Dr. Charles Kingston, a professor at the John Jay College of Criminal Justice (N.Y., N.Y. 10010), tabulated the responses.

The tabulated results are:

Question 1

	Responses
No need	8
Some need	12
Substantial need	52
Critical need	32
	Total 104

Question 2

	Responses
Glass	62
Hair (human)	58
Paint (general)	50
Soil	44
Blood	37
Fibers	36
Drugs	17
Paints (auto)	13
Tool marks	12
Safe Insulations	10
Gunshot residue	10
Petroleum products	9
Bullets	9
Metals	7
Explosives	7
Fingerprints	6
Plastics	5
Building materials	5
Body fluids	5
Inks	3
Plant materials	3
Wood	2
Shoe & heelprints	2
Firearms	2
Total	414

APPENDIX B

Brunelle's Survey/Results

About 500 questionnaires were distributed, under the aegis of the AOAC, to: its members, the Am. Academy of Forensic Science, International Association of Identification, and to other members of the Forensic Science community. 125 of the questionnaires were completed and returned. The responses were tabulated by Richard Brunelle of ATF.

Of particular interest to this report was the last question in the AOAC survey, which asked for the types of evidence which need study (for questionnaire), in order of frequency. The ranked responses are:

1. Hair
2. Paint
3. Soil
4. Gunshot residues
5. Glass
6. Explosive residues
7. Narcotics and Drugs
8. Biological stains
9. Fibers
10. Handwriting
11. Bullets
12. Tissue toxicology
13. Safe insulation
14. Ink
15. Paper
16. Firearms

APPENDIX C

PARKER'S SURVEY/RESULTS

The following are reproductions of tables taken from a paper [PA–1] by Brian Parker et al. The data presented in Tables C1, C2, and C3 is based on an actual sampling of crime scenes.

Physical Object Categories:

1. *Toolmarks*—Includes all physical evidence where it was evident that one object, serving as a tool, acted on another object, creating impressions, friction marks, or striations. A screwdriver, pipe, pry bar, fender of an automobile, or barrel of a gun could all produce toolmarks.
2. Fingerprints and Palmprints—Includes all prints of this nature, including bare foot prints, glove, or other fabric prints, either latent or visible.
3. *Organic, botanical, zoological material and unknown stains*—Includes matter of organic origin, or stains of nonorganic nature. Excreta, all residues from trees and shrubs, and food items are typical examples.
4. *Glass or plastic fragments*—Broken or chipped glass or plastic, resulting from the responsible's actions, or transferred to person(s) involved in the offense.
5. *Paint*—Liquid or dried paint in positions where transference would be possible to persons in that area. Freshly painted locations, cracked and peeling paint on window sills, and automobile collisions are leading examples.
6. *Tracks and Impressions*—Includes skid and scuff markings, shoe prints, depressions in soft vegetation or soil, and all other forms of tracking. Conventional tool marks are not included in this category.
7. *Clothing*—Clothing left, carried, removed or discarded by persons. Individual fiber characteristics are included in a separate category.
8. *Wood fragments*—Results from cases where forces have created fragmenting or splintering in areas where transference was likely. Prying, kicking, and chopping attempts at entry points were the most frequent examples.
9. *Dust*—All cases where "dust" (all types of surface contamination) was noticeably disturbed by someone.
10. *Cigarettes, matches, related ashes*—Discovery of any of these combustible items which were in such position that their relationship to responsibles was likely.
11. *Paper,* in various forms—There are two basic areas of identification for paper. First, where the paper itself might be traced to its original position or orientation, and second, where external information including latent prints and other contaminating substances might be present on the paper.
12. *Soil*—The presence of soil or soil-like material in locations where identification or individualization seemed possible.
13. *Fibers*, natural or synthetic—Fibers were often found near sharp corners or edges, or on objects where electrostatic or mechanical forces caused a transfer.
14. *Tools and weapons*—Cases where tools and weapons were found at crime scenes or in automobiles and where there was a strong likelihood that they were involved in this or another criminal offense.
15. *Grease and oil*—Any lubricant or fatty substance, often possessing environmental contamination, that was in a position to suggest involvement in the crime.
16. *Documents*—Of such quality that their origin may be traced to a person or instrument. Suicide and robbery notes would be of this type. Also cases where instruments were stolen (check

protectors) that could be traced back to a product of that particular instrument, in possession of rightful owner.

17. *Containers*—All bottles, boxes, cans and other containers which might hold residues or material of helpful nature.
18. *Construction and packing material*—All those substances commonly found in construction or packing areas, which don't belong to any of the other classifications.
19. *Metal fragments*—Industrial machining areas, scenes or objects of collisions, and other scrapings that would probably result in transfers to persons or objects in the vicinity.
20. *Hair*—Any animal or human hair discovered in an environment which could link a person with that particular area.
21. *Blood*—All suspected blood, liquid or dried, animal or human, present in a form to suggest a relation to the offense or persons involved.
22. *Inorganic and mineralogical substances*—All substances, and otherwise not belonging in another category, that could be classified under one of these headings, and bearing a relationship to the offense or offender.

Misc. *Other* category—Miscellaneous.

Table C1. Rate of Occurrence of Physical Object Categories By Suspected Offense Class

Physical Object Category	Burglary, Residential	Burglary Non-Residential	Burglary Auto	Total	Auto Theft	Theft	Robbery	Rape	Assault/ Battery	Murder	All Others	Total
Toolmarks	.39	.68	.54	.46	.39	.24	.10	.0	.2	.4	.32	.43
Fingerprints	.41	.46	.41	.42	.45	.45	.29	.3	.4	.4	.27	.41
Organic Substance	.35	.19	.10	.28	.31	.18	.14	.5	.2	.4	.14	.27
Glass	.16	.38	.32	.23	.15	.06	.00	.2	.2	.2	.50	.21
Paint	.21	.23	.09	.20	.24	.12	.00	.5	.0	.2	.32	.20
Track	.23	.31	.04	.22	.10	.09	.10	.3	.2	.2	.18	.20
Clothing	.17	.09	.16	.15	.20	.09	.19	.8	.2	.2	.18	.16
Wood	.20	.32	.03	.20	.04	.00	.05	.0	.0	.2	.09	.16
Dust	.20	.13	.06	.17	.13	.09	.10	.3	.0	.0	.05	.15
Cigarette	.09	.19	.07	.11	.29	.18	.38	.5	.0	.2	.14	.15
Paper	.07	.19	.10	.10	.31	.12	.19	.2	.0	.0	.18	.13
Soil	.14	.09	.04	.12	.23	.03	.05	.2	.2	.4	.05	.12
Fibers	.15	.14	.04	.13	.01	.03	.14	.0	.0	.0	.05	.11
Tools	.05	.22	.09	.09	.09	.09	.19	.2	.4	.4	.05	.10
Grease	.05	.16	.04	.07	.09	.12	.00	.2	.0	.0	.05	.07
Document	.05	.16	.03	.07	.10	.06	.05	.0	.0	.0	.05	.07
Container	.05	.04	.06	.05	.09	.12	.00	.0	.2	.2	.41	.07
Construction Material	.08	.11	.03	.08	.04	.00	.00	.0	.0	.0	.14	.07
Metal	.03	.10	.04	.05	.05	.09	.00	.2	.0	.2	.14	.05
Hair	.06	.05	.01	.05	.03	.03	.10	.5	.0	.0	.09	.05
Blood	.02	.6	.00	.03	.05	.03	.14	.2	.6	.6	.23	.05
Inorganic Substance	.03	.09	.00	.04	.03	.00	.00	.0	.0	.0	.14	.04
Miscellaneous	.09	.07	.12	.09	.14	.09	.05	.2	.2	.2	.09	.10

Table C2. Physical Object Categories Per Arrest

Suspected Offense	No. of Cases Involving Arrests	Physical Object Category 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Misc.	Total	Total Cases With Objects
Burglary																										
Res.	54	15	61	18	12	11	7	9	11	9	3	4	6	9	3	1	2	4	4	0	3	3	2	3	200	48
Non-Res.	13	7	11	4	4	2	1	1	4	0	2	4	1	1	2	3	2	0	1	0	1	1	1	2	55	11
Auto	11	2	11	0	0	1	1	2	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1	21	9
Auto Theft	15	6	9	5	3	3	2	3	1	2	4	3	3	1	2	0	2	1	0	2	0	2	0	2	56	14
Theft	7	2	3	1	0	0	0	1	0	0	2	1	0	1	0	0	1	0	0	0	1	0	0	2	15	5
Robbery	10	1	3	1	0	0	1	2	0	1	3	2	1	2	3	0	1	0	0	0	2	2	0	0	25	10
Rape	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	4	1
Assault/ Battery	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	1
Murder	2	1	2	1	0	0	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	9	2
All Others	5	1	2	0	0	4	4	1	1	1	1	1	1	0	0	1	0	0	0	1	2	2	1	0	24	5
Total	119	35	104	31	20	21	17	21	17	13	17	15	12	14	12	5	8	5	5	4	10	12	4	10	412	106

Table C3. Physical Object Categories Per Known Suspect Case

Suspected Offense	No. of Cases	Physical Object Category																							Total	Total Cases With Objects
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Misc.		
Burglary																										
Res.	38	14	20	7	3	7	3	3	11	10	4	3	2	7	3	2	2	2	3	1	2	2	1	2	114	36
Non-Res.	14	11	9	3	4	4	6	0	7	1	3	3	2	1	6	3	2	1	0	3	1	0	0	1	71	14
Auto	9	7	3	0	4	1	0	1	0	0	1	2	1	1	0	0	0	2	0	0	0	0	0	0	23	8
Auto Theft	3	1	1	2	0	1	0	0	0	0	1	1	1	0	1	1	0	0	0	0	1	0	0	1	12	2
Theft	3	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2
Robbery	3	0	2	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	5	3
Rape	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Assault/Battery	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
Murder	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
All Others	11	2	3	2	1	0	0	2	1	0	1	1	0	0	1	0	1	4	0	1	0	3	2	1	26	7
Total	83	36	39	14	13	13	9	6	19	11	12	11	6	9	12	6	5	9	3	5	4	5	3	6	256	74

APPENDIX D

Benson's Survey/Results*

Distribution of Physical Evidence By Type of Crime

Evidence item	Frequency of Occurrence	Percentage
Crime: Homicide		
Number Cases: 19		
Latent Prints	4	21
Gun	16	83
Other Weapon	2	11
Bullet or Slug	13	67
Hairs and Fibers		
Shell Casings	3	16
Powder Residue	9	47
Blood	3	16
Semen		
Fingerprints	2	11
Explosive Fragments		
Charred Specimens		
Clothing	1	5
Soil Sample	2	11
Paper Products		
Tissue Samples	1	5
Marks and Impressions	1	5
Petroleum Products		
Crime: Rape		
Number Cases: 14		
Latent Prints	11	79
Gun		
Other Weapon		
Bullet or Slug		
Hairs and Fibers	13	93
Shell Casing		
Powder Residue		
Blood	8	57
Semen	6	43
Explosive Fragments		
Charred Specimens		
Clothing	3	21
Soil Sample		
Paper Products		
Tissue Samples		
Marks and Impressions		
Petroleum Products		
Cosmetic Articles	1	7

*[LE–3], p502]. This survey contains data from several sources, including the Metropolitan P.D. of D.C., the Department of State Police in Oregon and the Bureau of Identification in Illinois.

APPENDIX E

Sample Questionnaire

The following pages contain a reproduction of the questionnaire used by the author in obtaining some background data. This questionnaire was submitted to those agencies whose opinions were highly valued but which, due to logistical problems, could not be surveyed by means of phone or actual visit.

STANDARD REFERENCE COLLECTION (SRC) QUESTIONNAIRE (FOR ADVANCED REVIEW PURPOSES PRIOR TO PERSONNEL INTERVIEWS)

1.0 General Background Information

1.1 Organization (agency, institution) name and address
1.2 Name of person(s) responding to questionnaire and title(s)
1.3 Date

2.0 Present Status of Surveyed Laboratory

2.1 How many full time trained criminalists does your laboratory employ?
2.2 What scientific instruments costing > $1,000 does your lab have ready access to? Please list in the order of frequency of use.
2.3 How many examinations/year are made with each of the above instruments?
2.4 Are the examinations (2.3) of the "identification," or "comparison" (individualization) type? Give the percentage of each.
2.5 What typical materials do you examine with each instrument?
2.6 What SRCs do you routinely use? In what form are they generally in? Assume SRCs to include: collections/compilations of photomicrographs, slides, spectra, characterization data; actual specimens/materials; compendiums relating to SRC classes; articles or books, etc.
2.7 Which SRCs do you use with what instrument(s)?
2.8 What would you estimate to be the frequency (per year) with which you use each SRC?
2.9 What is your source of each SRC (of 2.6)? Some potential sources might be: In house, state agency, federal agency, computer linkup to N.C.I.C., a local university, etc.
2.10 What instruments, tests, techniques (expertise), or SRCs do you consider to be somewhat unique to your lab?
2.11 What computer facilities, if any, does your laboratory have easy access to?
2.12 What procedural manuals, if any, do you use (or have you used) in conjunction with which analyses?

3.0 Your Standard Reference Collection Needs

3.1 Which SRC would:

a. Signficantly expand your investigative capabilities into areas of experienced needs? *and/or*

b. Significantly improve your sensitivity (i.e. decrease the uncertainty associated with the test's result)? *and/or*

c. Significantly improve your efficiency with regards to the test (i.e. decrease the cost or effort required to perform the test by means of a SRC without any loss in sensitivity or resolution?)

3.2 What would be the most useful and practical form(s) of each SRC? The following list is a partial list of possible SRC forms. Please feel free to give forms not included in this list.

3.2.1 A compilation of suitable spectra (using standard instrument, calibration settings, and procedure, etc.) in looseleaf; updateable form for your laboratory's retention.

3.2.2 A compilation of suitable characterization data in looseleaf; updateable form for your retention.

3.2.3 A physical specimen file for your retention.

3.2.4 A physical specimen file whose elements were available, via loan, to a select set of agencies for nondestructive examination.

3.2.5 A physical specimen file whose elements, or aliquots thereof, were available to a select set of agencies for destructive examination.

3.2.6 A compilation of photos or slides in updateable form for your retention.

3.2.7 Same as 3.2.6—but, due to costs or size prohibitions, available in form (whole collection or elements thereof).

3.2.8 Characterization data file available upon request from computer terminal linked to a central computer containing the data base.

3.2.9 Same as 3.2.8—but, computer is able to analyze data and make statistical inferences.

3.2.10 A manual or book containing: test procedures, population statistics, or manufacturing data, etc.

3.3 What other side benefits might be possible if the SRCs you have listed were made available to you? (e.g., instructional, calibration standards for consistency, intercomparison ability between yours and other labs leading to uniformity, etc.)

3.4 For each SRC listed in response to 3.1, 3.2—how extensive should the SRC be? (i.e. what is the minimum number of elements the SRC would have to contain to be of significant values to you to satisfy your present needs?) Describe the elements

3.5 To which agencies/groups should such SRCs be made available? (e.g., state, county crime labs, private individuals, universities, etc.)

3.6 For which SRCs are the sampling and/or analyses techniques so varied as to severely limit their utility? That is, before which SRCs are developed would it first be necessary to standardize the methodology? (This question applies particularly to those SRCs that would take the form of spectra or characterization data.)

3.7 For which SRC classes do you feel the variability (inter and intra), distribution patterns, or testing methodology, is such as to severely limit statistical inference possibilities.

4.0 Existing SRCs

4.1 Please list any agencies, institutions, individuals, etc., that already have developed suitable SRCs (as per 3.1, 3.2), or at least have segments thereof. Include any SRCs that your own agency maintains or is developing.

4.2 What elements do these SRCs contain? What needed elements are still lacking? Is the SRC current?

4.3 Are any of the SRCs of 4.1 both suitable and available, in their present form, for utilization in a nationwide dissemination program? (include the possibility of copying the SRC and then distribution).

4.4 Which laboratories, agencies or individuals, either national or foreign, do you believe have the highest degree of expertise with regard to investigations involving each of the reference materials/classes of the appended list?

5.0 Further Considerations Regarding SRCs

5.1 Of the SRCs listed in response to 3.1—How many man years and dollars would you estimate might be required to put each in a form suitable for your laboratory's needs?

5.2 Where do you feel the principal effort would be required? (e.g., towards collation of data or spectra from the literature, preparation of a lab manual, actual obtention of data (spectra, characteri-

zation), collecting or assembling of samples obtained from manufacturers, investigation of the population statistics, etc.)
5.3 In your opinion, which individual, agency or institution would be the most appropriate one to develop, assemble, maintain, update, and/or disseminate each SRC of 3.1?
5.4 In what ways is your laboratory prepared to assist in the development, maintenance and/or updating of any of the SRCs of 3.1, 3.2?
5.5 What form(s) of geographical distribution(s), or Grid(s), do you feel would be suitable for sites of SRCs of forms 3.2.4, –.7,–.8,–.9.
5.6 What classes of SRCs do you feel are more appropriately maintained and disseminated at the local (say state or regional) level? (e.g., soil, woods, house or road constructional materials, etc.).
5.7 What do you think would be reasonable acquisition times for SRCs of forms 3.2.4, 3.2.7, 3.2.8, 3.2.9?
5.8 Does your laboratory, or one you know of, maintain a computerized SRC data base, or statistical or analysis programs related to SRC material tests?
5.9 Can you think of SRC classes that could be of potential use to forensic scientists (or at least to your lab), but are not on the appended list?
5.10 Could you put the appended SRC class list (plus any classes from 5.8) in order of most needed or useful to forensic scientists (or at least your lab)?
5.11 Could you improve on the classification scheme of appended SRC list?
5.12 Should each SRC class of form 3.2.4, 3.2.5, or 3.2.7, be made available on an element-by-element basis, or on an all-or-nothing basis? Give your reasoning.

6.0 Service Fees for Centralized SRCs

6.1 Once each SRC (3.1, 3.2) were established and made accessible, what would you estimate might be the cost of maintaining and updating it (keeping it current)?
6.2 With regard to SRC forms of paragraphs 3.2.1–3.2.3, and 3.2.6,—How much would your agency/lab be willing to spend to obtain each? (Note that even if such SRCs were established, it is possible that the costs involved might be covered by Federal or State funding sources).
6.3 With regards to SRC forms of paragraphs 3.2.4, 3.2.5, 3.2.7—what service fees, if any, would you consider reasonable for loan of a SRC or elements thereof.
6.4 With regards SRC forms 3.2.8 and 3.2.9—What yearly linkup charges would you consider reasonable for each type of service?

APPENDIX F

EQUIPMENT USED AND TESTS PERFORMED IN THE CRIME LABORATORY

Other surveys have dealt with equipment found in crime laboratories [JO–1]. The following is a list of those instruments common to moderate size (or larger) crime laboratories.

a. Microscopes—compound, stereo, comparison, phase contrast, dark field, polarizing and petrographic. Almost every item submitted to a crime lab is first examined microscopically. Stereo—or low power—microscopes are used for general examination; the criminalist going to the more powerful compound microscopes where greater magnification is required. A comparison microscope has duplicate stages, lighting and optics which permit the microscopic comparison of two objects—each image appearing in one eyepiece. Some microscopes have phase contrast and/or polarizing features which permit the examination and measurement of birefringent materials (such as fibers, glasses, soil constituents, etc). A petrographic microscope has these and other features which permit the detailed analysis of minerals. A compound microscope with a " dark field" feature is often used in examining biological fluids.

b. Spectrophotometers—Infrared (IR), visible and ultraviolet (UV) spectrophotometers are only second to the microscope in terms of their frequency of use in most crime laboratories. Generally, these instruments are used to characterize organic compounds (qualitatively and, sometimes, quantatively). With the addition of an "integrating sphere" a visible-region spectrophotometer can be used to quantify object spectral reflectance or transmission (i.e., "color").

c. Gas chromatographs (GCs)—these instruments, essentially chemical species separators, are typically used in conjunction with one of several types of detectors: When used with either flame ionization (FI), electron capture (EC) or thermal conductivity (TC) detectors, these paired devices generate "retention indices" which permit chemical constituent identification. Peak heights or integrated peak areas can be used to then quantify these constituents. Each of these detectors has a specific set of compounds for which it has a greater sensitivity or utility than the other two.

The Mass Spectrometer (MS) is a detector whose use in conjunction with a GC is of more recent vintage. The GC-MS pair permit very highly sensitive qualitative analyses of a wide range of chemicals.

A pyrolysis is sometimes used at the entrance port of a GC. Such a combination (P-GC) permits the analysis of solid materials such as dried paints, fibers, hairs, etc.

Other types of chromatographic analyses are also performed in many crime laboratories. Among such analyses are gas-liquid chromatography (GLC), paper chromatography, and thin layer chromatography (TLC). TLC is presently being used for ink and drug identification.

d. Differential thermal analysis (DTA) and differential scanning calorimetry (DSC)—These are different means of measuring the differential thermal capacity and thence the crystal states and transition temperatures of chemical compounds. These means are used to, among other things differentiate glasses and to identify the mineral constituents of soils.

e. Breath and/or blood-alcohol analysis instrumentation—A variety of devices fall into these categories, including GCs and dialysis units.

f. X-ray diffraction (XRD)—These devices are used to identify chemical constituents by their known crystalline structures. XRD is particularly useful for inorganic analyses.

g. UV fluorescence—This inexpensive, simple, nondestructive method is useful in differentiating some glasses, soils, residues and "invisible" markings (e.g., laundry marks).

h. Emission spectrometers—These instruments, when used in conjunction with densitometers, are capable of accurate inorganic qualitative analyses. Except in the case of prototype Laser

Emission Spectrometers, a portion of the material submitted to such an analysis is inevitably evaporated and lost.

i. Atomic absorption (AA) analysis—AA permits very accurate elemental quantification. Since the device is generally only set to measure a very limited set of elements for a given analysis, the analyst should have prior knowledge of the elemental constituents in the sample.

j. Electrophoresis—(This is more of a technique than an instrument.) This is a technique used in the typing of blood, which requires equipment that can be purchased or, in part, can be home made.

A few laboratories also have (or have access to) the following instruments:

k. Scanning electron microscope (SEM) or electron milliprobe or micropobe—The SEM is used to obtain highly magnified images. Frequently, an SEM can be adapted to permit elemental mapping of specimens, on a micro-scale, by detection of X-rays emitted when the examined specimen is bombarded by electrons, e.g., X-ray fluorescence.

l. Nuclear activation analysis (NAA)—Nuclear activation of samples and their subsequent counting with standard radiation detection equipment permits highly sensitive, nondestructive elemental analysis of almost any type of material. At present, there are still bugs to be worked out of this technique; but when it is perfected, it should prove a boon to the qualitative and quantitative analysis of a wide range of forensic materials.

m. Thermoluminescence (irradiation facility and photometer)—This technique has been shown [IN–1] to be capable of differentiating glasses, soils and other nonmetallic solids.

n. X-ray fluorescence—This technique is useful in nondestructively differentiating small amounts of glasses, paints, dust, soils, gunshot residues and other organic and inorganic materials.

Other equipment indigenous to chemistry laboratories (e.g., hot plates, vacuum pumps, stirrers, etc.) can also be found in most crime labs.

APPENDIX G

An Analysis of the Degree of Need, Optimal Form and Viability of an SRC for Each of the FSM Classes in Table 2

For the purpose of ranking the 34 FSM classes of table 2, an "acceptability filter" was developed by the author. This filter is, in essence, a set of basic questions that must be addressed to each FSM class in order to ascertain the optimal form of an SRC for that class and the need for, and viability of, such an SRC. This "acceptability filter" is presented in figure G1 in schematic form. Such a simplistic filter cannot precisely reflect all the considerations that went into the recommendations put forth in this report, but the filter was used to assist the decision-making process. As will be seen, the results indicated in table G1 did, with a few minor exceptions, closely mirror the conclusions presented in section 4.

An Explanation of the Analysis Found in Table G1

The first two columns of table 3 list the 34 FSMs, tabulated in table 2, by number. The SRC forms selected for consideration for the FSM classes are given, cryptically, in the third column. The next set of eleven columns correspond to the eleven questions comprising the acceptability filter. These relate to the need and potential value/viability of SRCs of the indicated forms. These questions are analogous to filter "stages" and the ease with which, say, the jth FSM class passes through the ith stage of this filter is given a numerical value, A_{ij}. These A_{ij} values have the following interpretations:

A-VALUE	INTERPRETATION
0	This FSM class does not pass through this "neck" of the "acceptability filter" at all.
1	This FSM class passes through this "neck" of the "filter" with great difficulty.
2	This FSM class passes through this "neck" of the "filter" with little difficulty.
3	This FSM class readily passes through this "neck" of the "filter."
$n \rightarrow m$	This FSM class passes through this "neck" of the "filter" with a degree of difficulty ranging from $n \rightarrow m$ $(0 < n < m < 3)$.
NA	Not Appropriate—Disregard this element (A_{ij}) of table G1 since the i^{th} question was not relevant for the j^{th} FSM class.
?	No estimate is available, so this element (A_{ij}) is not operational.

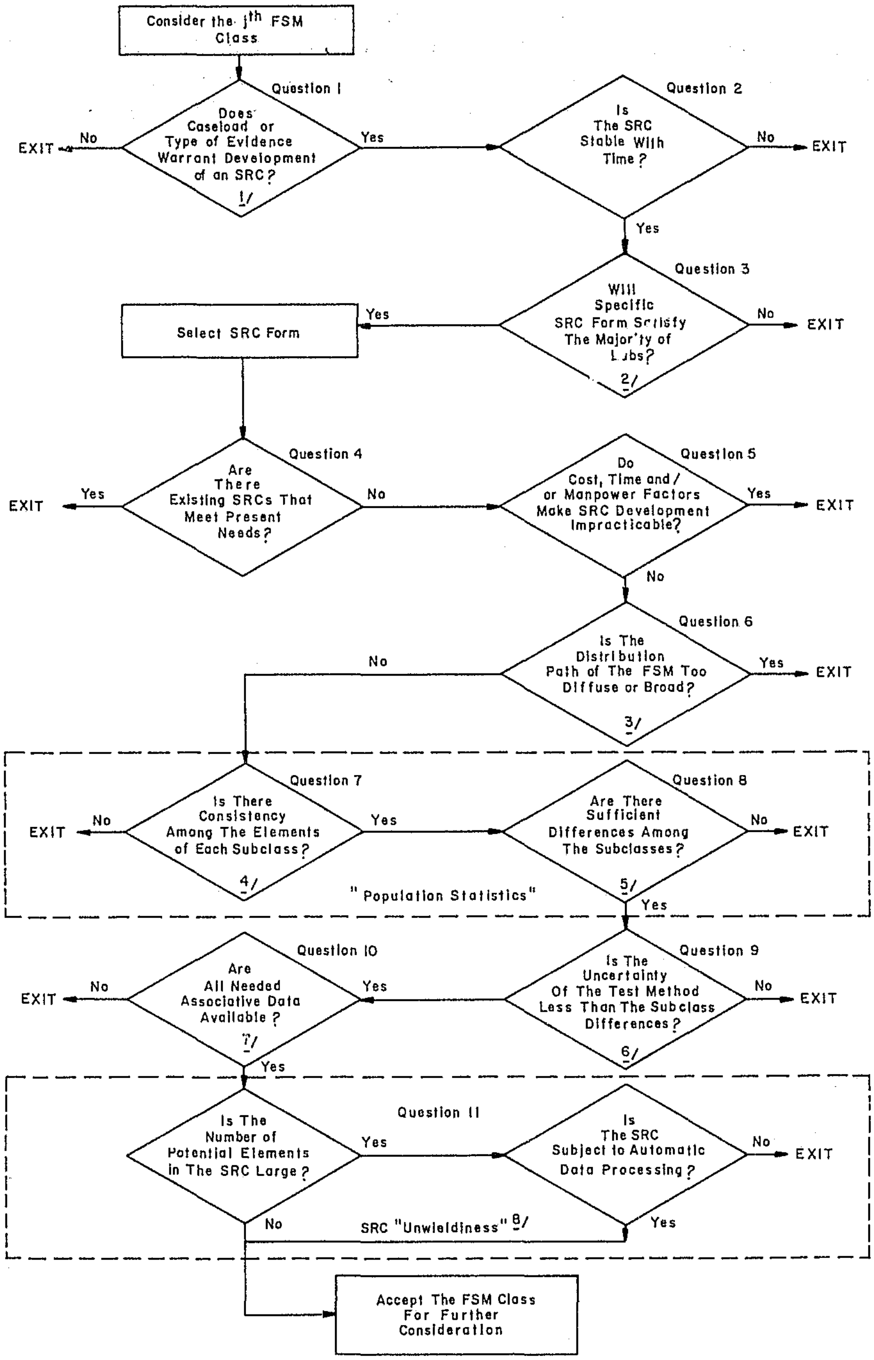
As is evident in table G1, a considerable number of the A responses were either "NA" or "?". In the final analysis, these filter stages had to be ignored. Thus, in the column labeled "N", is tabulated the number of operational stages for each FSM class.

The filter analogy is intended to imply that the FSM class can be "trapped" in any of its (operational) stages. That is, an "exit" type response to a given question should tend to eliminate a FSM class from SRC consideration, irrespective of how well it passes through the other filter "stages." In reality, as is evident from table G1, clear cut responses (Aij values of 0 or 3) are the exception rather than the rule. Nevertheless, the rationale of the analysis should be to tend to exclude from present consideration those FSM classes that are stopped at any filter stage. For this reason, the Aij (response) values were combined in product form to produce the Pj values found in column 16. Since no clear cut exit-type responses (i.e., Aij=0) were assigned, and since the number of operational filter stages for each FSM class (Nj) was not a constant, these Pj values have no intrinsic interpretation.

Therefore, it is necessary to normalize these Pj values utilizing the N's. It was assumed that, as each Aij could take any value from 0 to 3, an average Aij of about 1.5 would obtain. Thus, division of each Pj value by the Dj ($=1.5_{NJ}$) generated the normalized factors R)=Pj/Dj). Once the values had been reduced to a common basis, it was possible to numerically rank them.

Again, these numerical rankings, tabulated in the last column of the table G1, are intended to serve strictly as a guide to the recommendations made in Section 4. These recommendations, can however, be seen to closely follow the rankings generated by the mathematical analysis.

Figure G1. FSM Class Acceptability Filter



[1] Might be small caseload (say, involving explosives evidence) but severity of crime warrants action.

[2] Various analytical techniques may be used—want to supply spectras, characterization data or physical specimens as the majority needs but can't supply all required SRC forms. An accepted procedure is assumed.

[3] For example, are distribution records for firearms or ammunition such as to throw light on the sources of such materials?

[4] For example, an individual's hairs vary so much as to vitiate hair as good evidential material.

[5] For example, are the R.I.'s of auto lenses made by different Co's significantly different from one another?

[6] For example, can one differentiate a nylon fiber as to manufacturer based on pyrogram SRC?

[7] For example, what good is a typewriting SRC if manufacturing dates and distribution paths are not known?

[8] These questions are evaluated in tandem as "Question 11" in the analysis.

Table G1

A Mathematical Analysis of the Acceptability of 34 FSMs As Potential Candidates for SRC Development

j^{th} Value	FSM CLASS DESCRIPTION	SRC FORM (S)	ACCEPTABILITY FILTER QUESTIONS (A_{IJ}) i=1	2	3	4	5	6	7	8	9	10	11	N	$P_J =$ 11 $''_{IJ}$ $i=1$	$D_J = 1.5^{nJ}$	$R_J = P_J D_J$	Relative Ranking
1	Drugs	Physical Specimens	3	2	2	1	2	NA	2	1–2	2–3	2	1–2	10	540	57.7	9.4	8
2	Solid Dose Drugs	Cross Between PDR & Gupta & Kofoed	3	2–3	3	1–2	2	1	2	1–3	1–3	2	1	11	1080	86.5	12.5	2
3	Tobacco	Cigarette Paper, Filters	1	3	?	3	3	1	?	?	?	?	1	6	27	11.4	(2.4)	-
4	Alcohol	Physical Standards of ETOH in H_2O	3	1–2	2	2	2	NA	NA	NA	NA	3	NA	6	108	11.4	(9.5)	6
5	Cosmetics	Physical Specimens or Char-acteriz' n Data	1	2	?	1	1	1	?	?	?	?	0–1	6	1	11.4	(0.1)	-
6	Hair, Human	Representative Subclass Specimens	2	3	2	1–2	2	NA	1–2	1	?	1–2	2	9	162	38.4	4.2	18
7	Hair, Animal	Specimens, Photomicrographs, Data	1	3	3	2	2	NA	?	2	?	1–2	1–2	8	162	25.6	6.3	13.5
8	Blood, Human	Population Statistics, USA	2	0–3	2–3	1–2	1–2	NA	3	2–3	2	1–2	1–2	10	569.5	57.7	9.9	5
9	Blood, Animal	Physical Specimens	1	1–2	2	1–2	2	NA	?	?	2	?	2	7	36	17.1	(2.1)	-
10	Body Fluids	Animal Semina Photomicrographs	1	1	2	?	3	NA	3	?	?	?	3	6	54	11.4	(4.7)	-
11	Prints (Finger)	Evaluation of Analysis Meth-odology	3	3	2	?	1–2	NA	3	2–3	NA	?	1	8	202.5	25.6	7.9	11
12	Prints (Voice	Research, Institute Convict File	1	3	?	?	2	NA	?	?	NA	?	?	3	6	3.4	(1.8)	

13	Paper, Writing	Physical Specimens	1	3	3	1	1–2	1	1–2	1–2	?	2	1	10	60.8	57.7	1.1	20
14	Water	Physical Specimens	1	3	3	1	2	1	3	2	2	2	1	11	432	86.5	5.0	17
15	Typewriting	Exemplars	2	3	2	1–2	1–2	1–2	2–3	1–3	1–3	2	1	11	810	86.5	9.4	8
16	Writing Inks	Characterization Data	2	1	1	2	1–2	1	0–2	1–2	1–3	1	1	11	18	86.5	0.2	24.5
17	Dyes, Stains	Characterization Data	1	2	?	1–2	1	1	?	?	1–2	1	1	8	4.5	25.6	0.2	24.5
18	Fibers, Synthetic	Specimens, Photomicrographs, Data	2	3	2	1	2	1	2	1–3	2	2	2	11	768	86.5	8.9	10
19	Fibers, Plant	Specimens, Photomicrographs, Data	1	3	2	2	2	1	?	1–3	2	2–3	1–2	10	360	57.7	6.2	15
20	Woods, Bark	Specimens, Photomicrographs, Data	1	3	?	2	1	1–2	?	1	1	2–3	1	9	22.5	38.4	0.6	22
21	Adhesives	Specimens, Characterization Data	1	2	?	?	?	1	?	?	?	?	?	3	2	3.4	(0.6)	-
22	Soils	Isopleth Maps by Element	1	3	1	2	0–1	1–2	1	2	1–2	1	0–1	11	6.8	86.5	0.1	26.5
23	Glass, General	Population Statistics	2	3	2	2	1	1	?	1–2	1	1–2	1	10	54	57.7	0.9	21
24	Glass, Auto	Population Statistics	1–2	3	1–2	2	2	1–2	?	2	2	2	2	10	648	57.7	11.2	3.5
25	Paints, General	Characterization Data, Pop. Statistics	1	2–3	1	2–3	0–1	1	?	2	1–2	1–2	0–1	10	7.0	57.7	0.1	26.5
26	Paints, Auto	Color Coded File	1–2	2–3	2	2	2	NA	2	1–2	2	2	1–2	10	540	57.7	9.4	8
27	Shoe Prints	Illustrations	2	3	3	2	1–2	1	?	2	2	?	1	9	216	38.4	5.6	16
28	Tire Treads	Illustrations	2	3	3	1–2	2	1	2	2	2	2	1–2	11	1296	86.5	15.0	1
29	Tread Composition	Characterization Data	1	2–3	1	2	1	1	?	?	?	1	1–2	8	7.5	25.6	0.3	23
30	Safe Insulation	Characterization Data	1	3	2	?	3	NA	?	?	?	?	3	5	54	7.6	(7.1)	-
31	Explosives	Physical Specimens, Data	2	2	2	1–2	2	?	1–2	1–2	?	2–3	2	9	270	38.4	7.0	12
32	Firearms	Rifling Card File, Mfg. Data	3	3	3	?	1	NA	2	1–3	1–3	2	1	9	432	38.4	11.2	3.5
33	Ammunition	Characterization Data	3	3	2	1–2	1–2	1–2	1–2	1–2	1–3	2	1	11	546.8	86.5	6.3	13.5
34	Accelerants	Characterization Data, Specimens	2	1	1–2	1–2	2	1–2	1–2	2	1–2	2	2	11	243	86.5	2.8	19

APPENDIX H

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