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Webb R. Gilmore

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## IDENTIFICATION OF EVIDENCE BY NEUTRON ACTIVATION ANALYSIS

### I. INTRODUCTION

In the recent Missouri case of *State v. Stevens*<sup>1</sup> defendant Daniel Stevens was convicted of the murder of his next door neighbor, Mrs. Elizabeth Abbott. Police officers investigating the crime found a pair of gloves and a blood-stained yellow shirt in a bush near defendant's house. Defendant admitted that he owned gloves and a shirt similar to those found but stated that he had lost the gloves and thrown the shirt away before the murder occurred. Three strands of hair were found on the shirt and the right hand glove. These hairs were subjected to neutron activation analysis along with known samples taken from Stevens and the victim. Through comparison, two of the unknown hairs were identified as coming from the victim and the other as coming from the defendant. An alteration thread taken from the yellow shirt also was subjected to neutron activation analysis and was identified as the same as another alteration thread taken from another shirt owned by the defendant. Dr. James R. Vogt, now manager of Nuclear Science Research at the University of Missouri, conducted the neutron activation analysis tests at the university's Research Reactor Facility. He gave testimony at the trial, as an expert witness for the state, on the process of neutron activation analysis and the above findings.

On appeal defendant contended that it was prejudicial error to permit an expert witness to so testify. Specifically, defendant contended that the qualification of the witness as an expert was not established and that there was no evidence that the machines or apparatus used in making the tests were functioning properly when the tests were conducted. He also contended that he was not given proper notice in advance of trial that the evidence based on neutron activation analysis would be offered. The Missouri Supreme Court rejected these assignments of error, and upheld the trial court's ruling.<sup>2</sup>

In the past decade forensic uses of neutron activation analysis and its evidentiary uses in the courtroom have appeared. The purpose of this comment is to consider the evidentiary uses of neutron activation analysis in court by analyzing the legal issues involved in determining the admissibility of scientific evidence and describing the neutron activation analysis process and its forensic applications.

### II. ISSUES INVOLVED IN DETERMINING ADMISSIBILITY OF SCIENTIFIC EVIDENCE<sup>3</sup>

#### A. In General

Generally speaking, the trial court, in determining the admissibility of expert testimony on scientific evidence, engages in a balancing process to

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1. 467 S.W.2d 10 (Mo. 1971).

2. *Id.* In the more recent Missouri case of *State v. Stout*, 478 S.W.2d 368 (Mo. 1972), evidence based on neutron activation analysis of blood was excluded. See text accompanying notes 52-53 *infra*.

3. This section discusses some of the basic issues which will usually be considered in determining the admissibility of scientific evidence. It is not intended

determine the probative value of the evidence. Appellate courts recognize a great deal of discretion on the part of the trial judge in weighing the probative value of the evidence against the dangers of prejudicing or misleading the jury, unfair surprise, confusion of issues, undue consumption of time, and so forth.<sup>4</sup> The trial court's ruling with respect to admissibility will not be disturbed on appeal unless there has been an abuse of discretion,<sup>5</sup> and the error in admitting the evidence has been shown to be prejudicial.<sup>6</sup> Though the trial court determines admissibility, weight and evaluation of testimony are questions for the jury.<sup>7</sup>

Professor Wigmore viewed the ascertainment of evidence by a scientific process as simply an enlargement of the capacity of natural senses by the aid of scientific laws and devices. Postulating that testimony based upon a scientific process must be trustworthy, Wigmore laid down three fundamental propositions that are relevant in determining the reliability and accuracy of such testimony: (1) the scientific process and apparatus in general must be accepted as trustworthy and dependable by the profession in the branch of science concerned; (2) the particular apparatus used by the witness must be accurate and constructed according to the accepted type; and (3) the witness using the apparatus and testifying must be properly qualified.<sup>8</sup> These propositions give rise to the basic issues involved in determining the admissibility of scientific evidence.

### B. *Reliability and Accuracy of the Scientific Process in General*<sup>9</sup>

The first issue in determining the admissibility of scientific evidence is the extent to which the scientific process involved must have gained scientific acceptance as being accurate and reliable.<sup>10</sup>

to cover all issues which might be encountered. Part IV of this comment discusses some other issues which have been encountered in cases where neutron activation analysis evidence was offered in evidence.

4. *United States v. Stifel*, 433 F.2d 431, 437 (6th Cir. 1970), *cert. denied*, 401 U.S. 994 (1971); *State v. Stevens*, 467 S.W.2d 10, 23 (Mo. 1971); *Housman v. Fiddymont*, 421 S.W.2d 284, 289 (Mo. En Banc 1967); *State v. Menard*, 331 S.W.2d 521, 525 (Mo. 1960); *State v. Terry*, 325 S.W.2d 1, 7 (Mo. 1959); *People v. King*, 266 Cal. App. 2d 437, 443, 72 Cal. Rptr. 478, 482 (1968); 29 AM. JUR. 2d *Evidence* § 825 (1967); 31 AM. JUR. 2d *Expert and Opinion Evidence* § 16, at 512; § 31, at 530 (1967); 23 C.J.S. *Criminal Law* § 858 (7) (1961); 32 C.J.S. *Evidence* § 458 (1964).

5. *Falke v. Snyder*, 459 S.W.2d 281, 284 (Mo. 1970); *Parlow v. Dan Hamm Drayage Co.*, 391 S.W.2d 315, 325 (Mo. 1965); *Langdon v. Koch*, 435 S.W.2d 730, 733 (Spr. Mo. App. 1968); *People v. King*, 266 Cal. App. 2d 437, 443, 72 Cal. Rptr. 478, 482 (1968); 31 AM. JUR. 2d *Expert and Opinion Evidence* § 31, at 531 (1967).

6. *White v. United States*, 399 F.2d 813, 819 (8th Cir. 1968).

7. *People v. King*, 266 Cal. App. 2d 437, 72 Cal. Rptr. 478 (1968); 31 AM. JUR. 2d *Expert and Opinion Evidence* § 16 (1967).

8. 3 J. WIGMORE, *EVIDENCE* § 795, at 189-90 (3d ed. 1940); J. WIGMORE, *SCIENCE OF JUDICIAL PROOF* § 220, at 449-50 (3d ed. 1937).

9. In *State v. Stevens*, 467 S.W.2d 10 (Mo. 1971), defendant did not challenge the reliability of the neutron activation analysis process.

10. C. McCORMICK, *EVIDENCE* § 170, at 363 (1954); J. RICHARDSON, *MODERN SCIENTIFIC EVIDENCE* § 6.16, at 151 (1961).

In determining the admissibility of results of a lie-detector test, the landmark case of *Frye v. United States*<sup>11</sup> approached the problem as follows:

Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs.<sup>12</sup>

Following the reasoning of *Frye*, most courts and writers have stated as the general rule that the results of scientific tests are admissible only if the scientific principle involved has been sufficiently established to have gained general acceptance as being reliable and accurate in the particular field in which it belongs.<sup>13</sup> However, courts have varied in the way they have applied the "general acceptance" rule.

The problem for the trial court is basically one of determining whether there is enough in the record to conclude that the scientific principle upon which the offered evidence is based is accurate and reliable enough to let the evidence go to the jury. This may be established in two ways: the court may take judicial notice of the scientific principle, or it may be established by expert testimony.

In some situations there may be general acceptance of a scientific principle to such an extent that there is no dispute as to its reliability and accuracy. In such a case the trial court may take judicial notice of the principle, and it naturally follows that the court will admit evidence based thereon provided that the other requisites for admissibility have been met.<sup>14</sup>

In other situations there may be sufficient dispute on the scientific principle to prevent the court from taking judicial notice. In such a case

11. 293 F. 1013 (D.C. Cir. 1923).

12. *Id.* at 1014.

13. *United States v. Stifel*, 433 F.2d 431 (6th Cir. 1970), *cert. denied*, 401 U.S. 994 (1971); *State v. Graham*, 322 S.W.2d 188 (Spr. Mo. App. 1959); *Huntingdon v. Crowley*, 64 Cal. 2d 647, 51 Cal. Rptr. 254, 414 P.2d 382 (1966); *People v. King*, 266 Cal. App. 2d 437, 72 Cal. Rptr. 478 (1968); *People v. Williams*, 164 Cal. App. 2d 858, 331 P.2d 251 (1958); *Coppolino v. State*, 223 So. 2d 68 (Fla. 1968), *cert. denied*, 399 U.S. 927 (1969); *City of Abilene v. Hall*, 202 Kan. 636, 451 P.2d 188 (1969); *State v. Coolidge*, 109 N.H. 403, 260 A.2d 547 (1969), *rev'd on other grounds*, 403 U.S. 443 (1971); *State v. La Forest*, 106 N.H. 159, 160, 207 A.2d 429 (1965); *McKay v. State*, 155 Tex. Crim. 416, 235 S.W.2d 173 (1950); E. CONRAD, *MODERN TRIAL EVIDENCE* § 711 (1956); 2 B. JONES, *EVIDENCE* § 457 (5th ed. 1958); C. McCORMICK, *EVIDENCE* § 170, at 363 (1954); 31 AM. JUR. 2d *Expert and Opinion Evidence* § 44, at 548 (1967).

14. C. McCORMICK, *EVIDENCE* § 170, at 363 (1954). Three Missouri courts have taken judicial notice of the dependability of the radar speedometer when properly functioning and operated. *Kansas City v. Hill*, 442 S.W.2d 89, 91 (K.C. Mo. App. 1969); *City of St. Louis v. Boecker*, 370 S.W.2d 731 (St. L. Mo. App. 1963); *State v. Graham*, 322 S.W.2d 188, 195 (Spr. Mo. App. 1959). *See also* *State v. Cary*, 99 N. J. Super. 323, 239 A.2d 680 (1968); *State v. Walker*, 37 N.J. 208, 181 A.2d 1 (1962); 9 J. WIGMORE, *EVIDENCE* § 2580 (3d ed. 1940); Rowell, *Admissibility of Evidence Obtained by Scientific Devices and Analyses*, 6 ARK. L. REV. 181 (1952); 5 FLA. L. REV. 5 (1952).

the court must rely on expert testimony to establish whether the scientific principle is accurate and reliable enough to let the evidence go to the jury. There are two approaches with respect to general acceptance, which the court could take in ruling on such expert testimony. First, instead of using the general acceptance rule as a criterion for allowing admissibility of scientific evidence, objections concerning general acceptance could go to weight and not to admissibility.<sup>15</sup> Thus, any relevant conclusions vouched for by a qualified expert witness would be admissible<sup>16</sup> unless other reasons for exclusion are present, e.g., the probative value is outweighed by dangers of prejudicing the jury.<sup>17</sup> However, it seems to be a more logical approach to consider the "general acceptance" rule as a standard for determining whether the particular scientific subject in question is a proper one for expert testimony. Just as there are some subjects on which expert testimony is not allowed because they are so easy or common that the jury needs no help in forming an opinion, there are likewise some subjects that are so novel or undeveloped that the court will not even let an expert offer an opinion thereon, because such an opinion would be a gross speculation rather than a well-reasoned and reliable conclusion. Thus, the general acceptance rule should serve as a judicial standard for drawing the line between the proper scientific subject for expert testimony, and the scientific subject that is at present too speculative for expert testimony.

It is difficult to determine which approach the courts are using in the exercise of their discretion in ruling on admissibility of scientific evidence based on a disputed principle.<sup>18</sup> In the first approach an objection to admissibility would be based on a ground such as that the testimony might prejudice the jury, while in the second approach the objection would be based on the ground that the subject is not proper for expert testimony. However, even though the objections may be in a different legal form, they actually present the same problem for the court to decide. That problem is whether the scientific principle upon which the evidence is based is accurate and reliable enough to let the evidence go to the jury.

### C. *Reliability and Accuracy of a Scientific Process in a Specific Case*

Once the trial court has passed upon the question of reliability and accuracy of the scientific process in general, the question remains whether

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15. *McKay v. State*, 155 Tex. Crim. 416, 235 S.W.2d 173, 175 (1950); C. McCORMICK, EVIDENCE § 170, at 363 (1954).

16. *State v. Menard*, 331 S.W.2d 521, 524 (Mo. 1960); *State v. Paglino*, 319 S.W.2d 613, 623 (Mo. 1958); C. McCORMICK, EVIDENCE § 170, at 363 (1954); 2 J. WIGMORE, EVIDENCE § 659 (3d ed. 1940).

17. C. McCORMICK, EVIDENCE § 170, at 363; § 169, at 360 (1954).

18. In *United States v. Stifel*, 433 F.2d 431 (6th Cir. 1970), the court held that the record supported the proposition that NAA has gained "general acceptance in the particular field in which it belongs." *Id.* at 441. But the court also stated that disputes about the technique used by the government's expert or the results of the test went to the quality of the evidence and were for consideration by the jury. Thus, this case illustrates that both the judge and the jury have their respective functions, but it is hard to draw a clear line between them. The judge must decide if the technique has gained "general acceptance," and, ultimately, only the trial judge can really determine what this term means.

the evidence derived from application of the scientific process is admissible in the particular trial. Since it is a foregone conclusion that the scientific process is a proper subject for expert testimony, the only two issues in this regard are whether the expert witness is qualified to testify and whether the equipment was properly functioning and operated at the time the evidence was derived.<sup>19</sup>

### 1. Qualification of Expert Witnesses

The qualifications of an expert witness must be determined relative to the particular field in which he is to testify at trial.<sup>20</sup> The burden is on the party offering the expert witness to present proof of his qualifications,<sup>21</sup> and to show that the witness has acquired, through education, training, or experience, superior knowledge of a subject on which the jury presumptively cannot form an intelligent opinion without the benefit of expert assistance.<sup>22</sup> The trial judge has considerable discretion in determining whether these criteria have been satisfied by the party offering the expert witness.<sup>23</sup> In *State v. Stevens*<sup>24</sup> the Missouri Supreme Court upheld the trial court's ruling that the witness was qualified as an expert because of his education and experience in the field of nuclear physics and his extensive experience with neutron activation analysis of various materials.<sup>25</sup> However, it is important to keep in mind that even though the trial judge finds a witness qualified to testify as an expert, the jury still evaluates his qualifications when determining the weight to be given to his testimony.<sup>26</sup>

### 2. Accuracy of Equipment, Procedures and Operator

The accuracy of the evidence offered must be established by showing that the machines or apparatus involved functioned properly.<sup>27</sup> In *State v.*

19. *State v. Stevens*, 467 S.W.2d 10 (Mo. 1971); *Kansas City v. Hill*, 442 S.W.2d 89 (K.C. Mo. App. 1969); *State v. Graham*, 322 S.W.2d 188 (Spr. Mo. App. 1959); *Crawley v. State*, 219 Tenn. 707, 413 S.W.2d 370 (1967); J. WIGMORE, *THE SCIENCE OF JUDICIAL PROOF* § 220, at 450 (3d ed. 1937); 29 AM. JUR. 2D *Evidence* § 823, at 912 (1967).

20. *White v. United States*, 399 F.2d 813 (8th Cir. 1968); *People v. King*, 266 Cal. App. 2d 437, 72 Cal. Rptr. 478 (1968); 2 J. WIGMORE, *EVIDENCE* § 555, at 634 (3d ed. 1940); 31 AM. JUR. 2D *Expert and Opinion Evidence* § 26, at 523 (1967).

21. *Crawley v. State*, 219 Tenn. 707, 413 S.W.2d 370 (1967); 31 AM. JUR. 2D *Expert and Opinion Evidence* § 31, at 532 (1967).

22. *State v. Stevens*, 467 S.W.2d 10 (Mo. 1971); *Housman v. Fiddymment*, 421 S.W.2d 284, 289 (Mo. En Banc 1967); *Shelby County School Dist. v. Herman*, 392 S.W.2d 609 (Mo. 1965); *Giambelluca v. Missouri Pac. R.R.*, 320 S.W.2d 457 (Mo. 1959); *Gaddy v. Skelly Oil Co.*, 259 S.W.2d 844 (Mo. 1953); *Edwards v. Rudowicz*, 368 S.W.2d 503, 506 (St. L. Mo. App. 1963); *Boutell v. Scott's Royal Tire Co.*, 365 S.W.2d 765 (K.C. Mo. App. 1963); *People v. King*, 266 Cal. App. 2d 437, 72 Cal. Rptr. 478 (1968); *Ward v. State*, 427 S.W.2d 876 (Tex. 1968); 31 AM. JUR. 2D *Expert and Opinion Evidence* § 26 (1967); 32 C.J.S. *Evidence* § 457 (1964).

23. Cases cited note 4 *supra*.

24. 467 S.W.2d 10 (Mo. 1971).

25. *Id.* at 23.

26. *People v. King*, 266 Cal. App. 2d 437, 72 Cal. Rptr. 478 (1968).

27. *State v. Stevens*, 467 S.W.2d 10 (Mo. 1971); *State v. Fields*, 434 S.W.2d 507 (Mo. 1968); *Kansas City v. Hill*, 442 S.W.2d 89 (K.C. Mo. App. 1969); *State v. Graham*, 322 S.W.2d 188 (Spr. Mo. App. 1959).

*Stevens* this was established by expert testimony that the equipment was working properly when the tests were conducted. This testimony was deemed sufficient to establish the prima facie reliability of the evidence offered, which must be rebutted by evidence to the contrary.<sup>28</sup> In addition, it must be shown that the operator of the equipment was sufficiently qualified to operate the equipment and that he followed accepted operating procedures. In order to demonstrate this, the operator should be present at trial and subject to cross-examination.<sup>29</sup>

### III. THE NEUTRON ACTIVATION ANALYSIS PROCESS<sup>30</sup>

Neutron activation analysis (NAA) is a sensitive nuclear method of qualitative and quantitative analysis of chemical elements, whereby traces of various elements in a substance can be identified and measured by analyzing the gamma radiation which they emit after being irradiated with neutron radiation.<sup>31</sup> The method may be used to detect the mere presence of certain elements, such as barium and antimony found in gunshot residue

28. *State v. Stevens*, 467 S.W.2d 10, 23 (Mo. 1971).

29. *State v. Fields*, 434 S.W.2d 507, 516 (Mo. 1968).

30. See generally W. CORLISS, *NEUTRON ACTIVATION ANALYSIS* (1964) [hereinafter cited as CORLISS] (single copies may be obtained free by writing USAEC, P.O. Box 62, Oak Ridge, Tenn. 37830); P. KRUGER, *PRINCIPLES OF ACTIVATION ANALYSIS* (1971) [hereinafter cited as KRUGER]; *ACTIVATION ANALYSIS PRINCIPLES AND APPLICATIONS* (J. Lenihan & S. Thomson eds. 1965) [hereinafter cited as *ACTIVATION ANALYSIS*]; *Watkins & Watkins, Identification of Substances by Neutron Activation Analysis*, in 15 AM. JUR. PROOF OF FACTS 115 (1964) [hereinafter cited as *Watkins*]; Comment, *The Evidentiary Uses of Neutron Activation Analysis*, 59 CALIF. L. REV. 997 (1971). For further reference to literature published on activation analysis, see NATIONAL BUREAU OF STANDARDS, U.S. DEP'T OF COMMERCE, TECH. NOTE No. 467, *ACTIVATION: ANALYSIS: A BIBLIOGRAPHY* (1969).

In addition, several important reports have recently been published by the U.S. Atomic Energy Commission, covering extensive research into NAA techniques performed in an eight year program at Gulf General Atomic, Inc. in San Diego, from 1962 to 1970. A comprehensive report covers research performed from the inception of the program in May, 1962 through May 1968. The comprehensive report is accompanied by an annual report covering the period from June, 1968, to May, 1969, and a final report on the eight year program. See UNITED STATES ATOMIC ENERGY COMMISSION, *APPLICATIONS OF NEUTRON ACTIVATION ANALYSIS IN SCIENTIFIC CRIME INVESTIGATION* (Comp. Rep. No. GA-9807, 1970; Ann. Rep. No. GA-9822, 1970; Fin. Rep. No. GA-10276, 1970) [hereinafter cited as *APPLICATIONS OF NAA*, with reference to the particular report]. (These publications may be obtained by writing the National Technical Information Service, U.S. Dep't of Commerce, Springfield, Va. 22151). See also text accompanying notes 85-96 *infra*.

Though activation analysis has applications in many diverse areas, and undoubtedly has potential for use in civil cases, the discussion in this comment deals with its application in forensic science and its use in criminal cases. There are different techniques of activation analysis and many different kinds of equipment may be used. The process described herein is one of the more common and sensitive methods used in forensic neutron activation analysis. See Guinn, *Neutron Activation Analysis and Its Forensic Applications*, in *PROCEEDINGS OF THE FIRST INTERNATIONAL CONFERENCE OF FORENSIC ACTIVATION ANALYSIS 7* (Rep. No. GA-8171, 1967) [hereinafter cited as Guinn] (This publication may be obtained by writing Gulf General Atomic, Inc., P.O. Box 608, San Diego, Cal. 92112).

31. *APPLICATIONS OF NAA* Comp. Rep. 5; KRUGER 1; Guinn 7.

on the hand of a person who has fired a gun, or it may be used to compare the elements in two samples, such as two strands of hair, to determine if they have a common origin, *i.e.*, they come from the same person.

NAA consists of two main steps: (1) production of radioactive nuclides<sup>32</sup> by irradiation<sup>33</sup> of a sample, and (2) detection, measurement and analysis of induced radiation.<sup>34</sup>

In the first step, the sample of material to be analyzed is irradiated or activated by bombardment with nuclear particles. This is usually done by placing the material in a nuclear reactor,<sup>35</sup> where it is subjected to thermal neutron radiation.<sup>36</sup> Any sample of material consists of a base material which contains traces of other elements.<sup>37</sup> Some of the trace elements are made radioactive when they are bombarded by neutrons inside the reactor. By means of a nuclear reaction<sup>38</sup> this converts stable nuclides of the elements into unstable radioactive forms called radionuclides. Specific elements always form specific radionuclides. Usually, the radioactive sample

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32. A "nuclide" is a grouping of nucleons (neutrons and protons) in the nucleus of an atom which is characterized by its atomic number (number of protons in the nucleus), mass number (total number of nucleons in the atom) and energy content. The term is often used interchangeably with the term "isotope," which may be more familiar to laymen. Isotopes are nuclides of a given atomic number but different mass number, *i.e.*, they are nuclides with the same number of protons but different number of neutrons. KRUGER, 4.

33. Being "irradiated" is the same as being "activated." This means that the sample is made radioactive. Thus, the nuclei of some of the atoms in the sample will be made unstable. These radioactive or unstable nuclei will undergo radioactive decay and thereby regain their stability by emission of radiation in the form of gamma rays, electrons, alpha particles and other nuclear species. See Lenihan, *Radioactivity*, in ACTIVATION ANALYSIS 3.

The general principles of radioactivation and radioactive decay are covered in nuclear chemistry and physics textbooks.

34. APPLICATIONS OF NAA Comp. Rep. 5; KRUGER 34; Guinn 7.

35. KRUGER 62. Nuclear reactors are the most common neutron sources and are capable of producing much higher neutron fluxes than other sources (neutron flux is the number of neutrons passing through a unit area in the reactor per unit time). This is important when a high sensitivity is desired, since sensitivity increases with higher neutron fluxes. Neutrons are produced inside the reactor by the process of nuclear fission. See Wainerdi, *Nuclear Reactors as Sources of Neutrons*, in ACTIVATION ANALYSIS, 47.

36. Thermal neutrons are those of relatively low energy and are sometimes called slow neutrons. "Thermal" refers to the kinetic energy of the neutrons, which is a function of their velocity (*i.e.*, how fast they are moving around inside the reactor). Thermal neutrons are in thermal equilibrium with the atoms inside the reactor, and have an average velocity which, at room temperature (68°F.), corresponds to a most probable kinetic energy of about 0.025 electron volts (eV). APPLICATIONS OF NAA Comp. Rep. 6; KRUGER 21.

37. Very small amounts of various elements in a material constitute its trace element composition. These trace elements may be thought of as impurities. There are countless ways in which substances can pick up trace elements. Common proportions of trace elements in a sample are in the parts per million (ppm) or parts per billion (ppb) range. Quantitative measurements of trace elements are usually given in micrograms per gram of sample or parts per million. Watkins 119, 123, 152.

38. Nuclear reactions are changes produced in nuclei by interaction with projectile nuclei, such as thermal neutrons, of sufficient energy to make the nuclei radioactive. KRUGER 21.



will then give off high-energy electromagnetic radiation called gamma rays.<sup>39</sup> This emission process is called radioactive decay. As the gamma rays are given off the radioactive nuclides return to a stable state. No two radionuclides decay with exactly similar patterns. It is the individuality of these gamma ray emissions that is the basis of NAA.<sup>40</sup>

In the second step the emitted gamma radiation is analyzed to determine what elements are present in the material and in what amount they are present. This step consists of counting (detection, measurement, analysis) the gamma rays given off to identify qualitatively and quantitatively the trace elements present. This involves the use of sophisticated electronic equipment to determine the half-lives<sup>41</sup> of the radioactive nuclei and also their gamma ray energies.<sup>42</sup> Together, these two parameters will qualitatively identify what particular trace elements are in the sample since each radionuclide has a unique combination of values for these parameters.<sup>43</sup> The counting process also determines quantitatively the amount of each trace element present.

NAA can be used not only to determine the trace element composition of a single material, but also to compare two or more specimens of apparently similar evidence materials for differences or common origin. The radiation of a known sample is compared with that of a unknown sample being tested. The results will indicate whether there is a probability that they have a common origin, *i.e.*, whether they contain the same trace elements in equal amounts per unit mass of material.<sup>44</sup> This technique is an application of the principle of trace-element characterization.<sup>45</sup>

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39. Gamma rays are a type of electromagnetic radiation which is quantized into discrete quanta called photons. Gamma radiation associated with radioactive decay results from the de-excitation of radioactive nuclei with excess energy. The energy of the nuclear transition is emitted as a discrete quantum called a photon. *Id.* at 19-20.

Though there are several principal forms of radiation emitted by radionuclides, usually only the gamma rays are measured in NAA. Watkins 154.

40. For a given transition in a specific radionuclide each gamma ray is emitted with the same energy. Therefore, specific radionuclides may generally be identified by their characteristic gamma ray energies. KRUGER 20.

41. Half of the radioactive atoms of a given radionuclide in a sample will disintegrate (*i.e.*, emit radiation and become stable) in one half-life. CORLISS 3. For a mathematical description, see KRUGER 15; Watkins 123.

42. By a typical method, the irradiated sample is placed in a gamma ray counter which records the number and energies of the gamma rays given off. Gamma rays given off by the sample interact with a solid state detector causing an electrical current to be produced. The current is then converted by a pre-amplifier into electrical pulses which have voltages proportional to the energy of the gamma rays. An electronic device called a multichannel pulse height analyzer then automatically sorts the electrical pulses into different energy groups and adds up the pulses in each group. The results may then be presented as a graph on an oscilloscope screen, or may be printed, or punched out on computer cards. These results reveal information relating to the kind and amount of elements in the radioactive sample. CORLISS 6, 23-26; KRUGER 118-19; Watkins 118, 146.

43. KRUGER 85. Since radionuclides have their own decay patterns, with characteristic half-lives and gamma ray energies, this method has been referred to as "nuclear finger printing." *Id.* at 455; Watkins 154-55.

44. Whether such a conclusion of common origin can be reached depends on statistical considerations. See part IV, § B of this comment.

45. Basically this principle states that substances having a common origin

NAA is also used to do macroanalysis to determine a sample's major element composition when the sample is too small to be analyzed by other means of elemental analysis.<sup>46</sup> However, NAA is most commonly used in forensic work to do trace element analysis.

#### IV. FORENSIC APPLICATIONS OF NAA<sup>47</sup>

##### A. NAA In Criminal Cases

##### 1. General Acceptance of NAA in Appellate Cases

To date the legal precedent on the admissibility of NAA tests, at the appellate level, is sparse. However, evidence based on NAA has now been held admissible in several appellate cases.<sup>48</sup> In these cases the courts accepted the reliability of NAA in general and its specific application in the particular case. In *United States v. Stifel*,<sup>49</sup> defendant was convicted of murder by sending a bomb through the mail which exploded when the victim opened the package containing the bomb. Expert testimony on NAA tests, showing the bomb package fragments to be of the same elemental composition and of the same type and manufacture as materials to which the defendant had access, was held admissible for the purpose of identifying the source of the fragments. In *State v. Stevens*, NAA evidence comparing hair and thread was held admissible.<sup>50</sup> A similar result was reached in *State v. Coolidge*,<sup>51</sup> where the court held that there was no error in admitting evidence of NAA tests on particles since it could be demonstrated that the tests were accurate and the procedures were sufficiently accepted by scientists in the field.

However, in *State v. Stout*,<sup>52</sup> the Missouri Supreme Court, while recognizing that NAA is a generally accepted scientific technique for analysis of certain materials, including hair, held that it is not as yet a generally accepted technique for comparison of blood samples. This case illustrates that even though NAA may be generally accepted as a scientific technique of chemical analysis, the issue must be narrowed to whether the technique

will be similar in base material composition and also in trace-element composition, whereas substances of different origins, although they may be similar in base material composition, will show significant differences in trace-element composition. APPLICATIONS OF NAA Comp. Rep. 3; Guinn 23.

46. Watkins 152.

47. Several extensive bibliographies of activation analysis in forensic science have been prepared. See, e.g., 15 AM. JUR. PROOF OF FACTS 52 (Supp. 1971); NATIONAL BUREAU OF STANDARDS, U.S. DEPT OF COMMERCE, TECH NOTE NO. 519, FORENSIC SCIENCE: A BIBLIOGRAPHY OF ACTIVATION ANALYSIS PAPERS (1970); Guinn, *A Forensic Activation Analysis Bibliography* (Rep. No. GA-9912, Gulf General Atomic, Inc., San Diego ed. 1970); Jervis, *Activation Analysis in Forensic Science*, in NUCLEAR ACTIVATION TECHNIQUES IN THE LIFE SCIENCES 645 (Int. Atomic Energy Agency, Vienna ed. 1967).

48. *United States v. Stifel*, 433 F.2d 431 (6th Cir. 1970), cert. denied, 401 U.S. 994 (1971); *State v. Stevens*, 467 S.W.2d 10 (Mo. 1971); *State v. Coolidge*, 109 N.H. 403, 260 A.2d 547 (1969), rev'd on other grounds, 403 U.S. 443 (1971).

49. 433 F.2d 431 (6th Cir. 1970), cert. denied, 401 U.S. 994 (1971).

50. See part I of this comment.

51. 109 N.H. 403, 260 A.2d 547 (1969), rev'd on other grounds, 403 U.S. 443 (1971).

52. 478 S.W.2d 368 (Mo. 1972).

is generally accepted for analysis of the particular type of evidence material in question.<sup>53</sup> For example, blood analysis by NAA presents two problems which may or may not be encountered with other materials. One is the problem of masking. Blood has a high trace element content of sodium and chlorine atoms. When they are activated, their emitted radiation is predominant and masks out radiation from other trace elements in the blood. In *Stout* the expert attempted to overcome this problem by use of a cadmium shielding technique to eliminate the activation of sodium and chlorine atoms. However, the court found that this technique was not yet generally accepted. Another problem in analyzing blood, which may be encountered with other materials, especially liquids, is contamination. When blood comes in contact with other materials, such as a shirt or a floor mat, it easily picks up impurities. Thus, the normal trace element content of the blood becomes distorted by the addition of new impurities, and it follows that NAA results will be unreliable. Since different materials may present different problems in the use of NAA it is very important to look beyond the NAA process in general and look to the specific material being analyzed and particular problems it may present.

Two other appellate cases, while recognizing the essential validity of NAA as a test, have rejected NAA evidence where the expert's testimony was not based on reasonable scientific certainty,<sup>54</sup> and where the prosecution failed to notify the defendant in advance of trial of its intention to use NAA evidence.<sup>55</sup> In neither of these cases was the testimony based on NAA rejected because the NAA process was found unreliable or lacking in general acceptance in its own scientific field. On the other hand, in *United States v. Wolfson*,<sup>56</sup> NAA tests, while not rejected, were not considered in weighing the evidence because testimony of defendant's expert witness left its reliability open to question. However, in this case the NAA evidence was not essential because of other evidence available on the same issue, and the court did not rule directly upon the question of its reliability.<sup>57</sup>

#### a. Necessity to Notify Defendant

While NAA evidence can meet the tests of admissibility in certain cases, the method can be abused. There is clearly a need for pre-trial discovery by defendant of results of NAA tests, and, in *United States v. Kelly*<sup>58</sup> the court held that the prosecution must give defendant adequate notice of its intent to use NAA evidence sufficiently in advance of trial. Such notice will insure that defendant has a fair opportunity to prepare his defense.<sup>59</sup> In *Kelly* the government had been ordered to allow discovery of its scientific tests and, under the Federal Rules of Criminal Procedure, was under a continuing duty to disclose new scientific tests as made.<sup>60</sup> Thus this decision,

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53. *Id.*

54. *State v. Holt*, 17 Ohio St. 2d 81, 246 N.E.2d 365 (1969).

55. *United States v. Kelly*, 420 F.2d 26 (2d Cir. 1969).

56. 297 F. Supp. 881 (S.D.N.Y. 1968).

57. *Id.* at 888.

58. 420 F.2d 26 (2d Cir. 1969).

59. *Id.* at 29.

60. *Id.* at 28.

in its narrowest reading, applies only to a situation where discovery has been ordered by the court, and does not answer the question of whether the prosecution has a duty to notify defendant of its intent to use NAA evidence when no request or court order for discovery is involved.

In *State v. Coolidge* the New Hampshire Supreme Court stated that the prosecution was not required in advance of trial to inform defendant definitely whether evidence of such tests would be used.<sup>61</sup> However, it appears from the decision that defendant was aware that the prosecution might use such tests and therefore was not deprived of an opportunity to defend against such evidence. In fact, defendant was prepared to meet the state's NAA evidence by calling his own expert witness at trial.<sup>62</sup>

In *State v. Stevens* defendant contended that he should have been notified in advance of trial that NAA evidence would be offered.<sup>63</sup> The court held that the endorsement as a witness of the expert who conducted the NAA tests, sufficiently notified defendant that evidence of the tests would be offered.<sup>64</sup> The trial court apparently would have directed that defendant be informed of the results of the tests if there had been a request, but defendant made no such request, and, as such, there was no wrongful concealment of the tests or their results.<sup>65</sup>

Usually it is the state which has access to the expensive and sophisticated NAA process, and it is unlikely that a defendant will have such access. Thus, in addition to the discovery problem, there is a further question as to fundamental fairness in the use of NAA; namely, if the state desires to introduce NAA evidence, must the defense be given adequate opportunity to run its own NAA tests? In *United States v. Kelly* the court stated that it is important that the defense be given a chance to research the techniques and results of scientific tests made by the government,<sup>66</sup> but said nothing about the opportunity for the defendant to make his own tests. However, in *United States v. Stifel* the court stated (in dictum) that the government must allow defendant time to make similar tests, and if defendant is an indigent, it must provide a means of payment for the tests.<sup>67</sup>

The problem of notification should not be a difficult problem under the Federal Rules of Criminal Procedure, where discovery of the results of scientific tests is permitted, or in state jurisdictions which have similarly liberal procedures for criminal discovery. However, without going into the uncertain status of criminal discovery, there is a serious constitutional question of whether defendant has a right to discovery of NAA evidence in cases where such is not provided for. A denial of access to the results of NAA tests would clearly prejudice the defendant's ability to have his own expert witness interpret the results and prepare to meet the evidence in

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61. *State v. Coolidge*, 109 N. H. 403, 415, 260 A.2d 547, 556 (1969).

62. *Id.*

63. *State v. Stevens*, 467 S.W.2d 10, 23 (Mo. 1971).

64. *Id.*

65. *Id.* at 24.

66. *United States v. Kelly*, 420 F.2d 26, 28 (2d Cir. 1969).

67. *United States v. Stifel*, 433 F.2d 431, 441 (6th Cir. 1970), *cert. denied*, 401 U.S. 994 (1971).

court. Indeed, in many situations it might even be necessary for the defendant to run his own tests in order to properly prepare his defense. These are serious questions which must be faced and which will have to be answered in future cases.

#### b. Degree of Certainty Required of Expert Testimony

In *United States v. Stifel* the court stated that neither newness nor lack of absolute certainty in a test should render it inadmissible in court.<sup>68</sup> Nevertheless, the question of the degree of certainty required for expert testimony on scientific evidence is still a problem. Missouri courts have often stated that an expert's opinion must not be a mere guess or conjecture but must be based upon facts and adequate data.<sup>69</sup>

In *State v. Holt*<sup>70</sup> the conviction was reversed because the expert testimony on NAA results was not expressed with the proper degree of certainty. The expert witness stated that "the samples are similar and are likely to be from the same source."<sup>71</sup> The Ohio Supreme Court concluded that such testimony should have been based on reasonable scientific certainty that the samples came from the same source, rather than mere likelihood.<sup>72</sup> In *State v. Coolidge* the analysis of hair samples was inadmissible because the expert witness claimed that the evidence was virtually infallible, but stated that the methods of analysis employed on the hair samples in this case would not be acceptable to scientists in the field.<sup>73</sup> In the same case other NAA tests of particles were admissible, even though the expert witness claimed only that the evidence showed a similarity of the particles, because the methods of analysis used were acceptable to scientists in the field.<sup>74</sup> Thus it seems that the degree of certainty to which an expert witness expresses his conclusions is a significant factor which the courts consider in determining the admissibility of expert scientific testimony. However, it is impossible to formulate any clear cut test for predicting the outcome in a particular case. Because of this, the attorney should be certain that the expert is aware of the importance of the selection of terms he uses to characterize his conclusions. For example, he should not use the word "likelihood" if he could just as easily say "reasonable scientific certainty."

#### 2. NAA in Trial Cases

Although the NAA process is a relatively new method in the field of criminalistics, and has been ruled on in only a few appellate cases, testimony on NAA results has nevertheless been received in many cases at the

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68. *Id.* at 438.

69. *Giambelluca v. Missouri Pac. R.R.*, 320 S.W.2d 457 (Mo. 1959); *Gaddy v. Skelly Oil Co.*, 364 Mo. 143, 259 S.W.2d 884 (1953); *Edwards v. Rudowicz*, 368 S.W.2d 503, 506 (St. L. Mo. App. 1963); *Boutell v. Scott's Royal Tire Co.*, 365 S.W.2d 765, 768 (K.C. Mo. App. 1963).

70. 17 Ohio St. 2d 81, 246 N.E.2d 365 (1969).

71. *Id.*

72. *Id.*

73. *State v. Coolidge*, 109 N.H. 403, 420, 260 A.2d 547, 560 (1969).

74. *Id.* at 422, 260 A.2d at 561.

trial level. To date there are at least 76 cases in which NAA evidence has been accepted by trial courts in the United States.<sup>75</sup> The physical evidence analyzed by NAA in these cases has included a wide variety of materials.<sup>76</sup> The enthusiastic use of NAA by a number of federal government agencies has been influential in increasing the use and acceptance of NAA evidence in federal and state courts.<sup>77</sup>

### B. *Developments of NAA in Crime Detection*

Neutron Activation Analysis has several advantages which make it superior to other types of analyses<sup>78</sup> for certain forensic purposes. NAA has a high degree of sensitivity<sup>79</sup> in determining the elements present in a sample, which makes it more precise than other techniques in determining trace element concentration.<sup>80</sup> It is particularly advantageous when analysis could not be performed with conventional methods, because of the small size of the samples or low concentrations of trace elements involved. Very small samples, such as hair or tiny pieces of automobile paint, can be analyzed and correctly identified by NAA.<sup>81</sup> Also, NAA is usually non-destructive, so that the evidence may be analyzed by another method or preserved for use in court.<sup>82</sup>

Numerous investigators have demonstrated the feasibility of using NAA in the field of crime detection. A great deal of diversified research has been conducted in this area. In addition, many articles, papers and books have been published on various developments in the useful forensic applications of NAA in the field of criminalistics.<sup>83</sup> Research and development has been conducted and is continuing with many different materials including gunshot residues, bullet residues, bullets, metals, moonshine, whiskey, water, drugs, tobacco, marijuana, opium, poisons, soils, charcoals, soots, paint, paper, plastics, wood, rubber, fabrics, rope, cord, tapes, glass,

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75. Watkins 19-27 (Supp. 1971).

76. *Id.*

77. *Id.* at 18-19.

78. For a list of other methods of elemental analysis, see CORLISS 7; GUINN 32.

79. Sensitivity refers to the minimum amount of an element that can be detected and measured in a sample. KRUGER 241, 368.

Sensitivity varies with neutron flux level, energy of the bombarding neutrons, irradiation time, counting time, efficiency of counting equipment, and the particular element being analyzed. APPLICATIONS OF NAA Comp. Rep. 11; CORLISS 7; Watkins 125.

80. APPLICATIONS OF NAA Comp. Rep. 11; Guinn 23; Watkins 119, 123.

81. APPLICATIONS OF NAA Comp. Rep. 5; Guinn, *Forensic Applications of Activation Analysis*, in ACTIVATION ANALYSIS 125; Watkins 119.

82. Guinn, *Forensic Applications of Activation Analysis*, in ACTIVATION ANALYSIS 125; Watkins 119.

The major disadvantages of NAA are the high cost of the nuclear reactor neutron source, the need for highly skilled and specialized personnel, and the need to work with radioactive materials and follow radiological health regulations and precautions. Furthermore, as with other sophisticated methods, there are technical problems and limitations associated with the NAA process. CORLISS 8; KRUGER 323; Watkins 51.

83. See bibliographies cited note 47 *supra*.

concrete, ink, blood, skin, fingernails, hair, sperm, urine, grains, kerosene, oil, automobile greases and solder.<sup>84</sup>

NAA is not as yet a highly developed and accepted technique for characterization of all of these evidence materials. Indeed, the technique has probably reached such a state of development with regard to only a few of these materials. Nevertheless, NAA is in a vigorously developing state and work on the application of NAA in scientific crime detection continues to develop improved techniques for the identification of many substances.

A good example of work in this area is the extensive research and development on the usefulness of NAA in the field of criminalistics which has been conducted by Gulf General Atomic, Inc., in San Diego. Over an eight year period from 1962 to 1970 a research program entitled "Applications of Neutron Activation Analysis in Scientific Crime Investigation" was conducted at Gulf General Atomic.<sup>85</sup> The program was supported by the United States Atomic Energy Commission (USAEC) and the Office of Law Enforcement Assistance of the United States Department of Justice.<sup>86</sup> During this eight year period the Activation Analysis Group at Gulf General Atomic studied possible forensic applications of NAA as an investigatory tool. NAA's nondestructive characterization of a wide variety of materials through their major and trace element contents was investigated. These investigations have demonstrated NAA to have significant potential in the examination of many of these materials.<sup>87</sup>

Most materials were studied with comparative brevity, but several materials of major interest to criminalists were selected for a more detailed study. These included gunshot residues, paint, paper, and bullets.<sup>88</sup> A major objective of the more detailed study was to develop sound statistics to back up conclusions that might be derived from the examination of the materials. By testing a reasonably large and representative sampling of these materials a background of statistical data was accumulated to provide a basis for proper statistical analysis and interpretation of the results of NAA tests run on a particular item.<sup>89</sup> Reliable statistical interpretation is the crux of meaningful evaluation of NAA results and the inferences drawn therefrom. For example, two samples which have nearly identical trace element concentrations do not necessarily have a common origin.<sup>90</sup> To provide a firm statistical basis for comparison, a great deal of background information concerning the existence of trace elements in various materials must be acquired. Only by analysis of many specimens of a particular material is it possible to give accurate testimony concerning the probability that two different samples originated from an identical source. The "identity" or "difference" of two samples can only be determined after comparison

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84. Guinn 25; Watkins 126-34; Watkins 32-49 (Supp. 1971).

85. See the material on the Gulf General Atomic research in note 30 *supra*.

86. APPLICATIONS OF NAA Comp. Rep. iii.

87. The materials studied in the program included the following: plastics, rubber, greases, oils, paint, glass, soils, paper, ink, hair, fingernails, wood, tobacco, drugs, water, whiskey, skin, marijuana, bullets, primers, and gunshot residues. APPLICATIONS OF NAA Fin. Rep. 2, 85.

88. *Id.* at 2-4, 85.

89. *Id.* at 2.

90. *Id.*

of the results of the NAA examination with properly developed statistical data.<sup>91</sup>

The work with these few selected materials demonstrated that a high degree of reliability can be achieved from the interpretation of NAA results. For example, NAA has been shown to be a highly reliable technique for detecting gunshot residues and determining whether a person has fired a gun. NAA also has been shown to have potential reliability in examining and identifying bullets. Examination of elemental concentrations of paint and paper by NAA has been shown to be an excellent method for determining whether two samples of material could have come from the same manufacturer and production batch.<sup>92</sup> Thus the work at Gulf General Atomic has expanded NAA as a means by which evidentiary materials can be characterized and has enlarged the basis from which statistical inferences can be made regarding individual applications of NAA data. By increasing the statistical accuracies with which statements based upon evidentiary materials can be made, the quality of testimony offered has been greatly improved.<sup>93</sup>

During this eight year program, other activities in which the Gulf General Atomic group was involved included the examination of evidence samples by NAA for use in actual court cases, the production of several films on NAA,<sup>94</sup> dissemination of information regarding the work through papers, lectures, and reports,<sup>95</sup> and participation in conferences, including the First International Conference on Forensic Activation Analysis.<sup>96</sup>

### C. Forensic NAA Services

#### 1. Missouri State-Wide Training and Service Program in Forensic NAA<sup>97</sup>

The University of Missouri is operating a state-wide program in forensic NAA which provides NAA services to Missouri law enforcement agencies. The program, which is directed by Dr. James R. Vogt,<sup>98</sup> provides on a routine basis the capability for characterization of certain types of physical evidence through the application of NAA. Close co-operation between law enforcement and scientific personnel is emphasized, from the search for evidence at the scene to the presentation of evidence in court. Therefore, a great part of this program is devoted to the training of law enforcement

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91. APPLICATIONS OF NAA Comp. Rep. 260.

92. *Id.* at 259.

93. *Id.* at iii.

94. APPLICATIONS OF NAA Ann. Rep. 93-94.

Three color films on NAA have been produced for the U.S. Atomic Energy Commission by Gulf General Atomic, and are available on a loan-free basis. Watkins 32.

95. APPLICATIONS OF NAA Comp. Rep. 251.

96. *Id.* at 246. A second international conference on forensic activation analysis is scheduled to be held in Glasgow, Scotland in September, 1972.

97. The material in this subsection is based on several interviews with Dr. James R. Vogt, Manager of Nuclear Science Research, Univ. of Mo., in Columbia, Mo., during Sept., 1971.

98. Manager of Nuclear Science Research, University of Missouri.



personnel in crime scene search techniques and proper sample collection and handling procedures. Instruction on the capabilities and limitations of NAA is also given. The three main phases of the program are training, research and development, and service.

#### a. Training

The training aspect of the program is run by the University's Law Enforcement Extension Education staff, who conduct training programs throughout Missouri. The training program provides three levels of instruction. The first level provides orientation for law enforcement administrative and prosecution personnel on basic concepts of NAA, its forensic applications, and the role of law enforcement agencies and personnel in the operation of the program. The orientation of prosecuting attorneys is important because they often decide what laboratory tests will be run and what evidence will be presented in court.

The second level is a lecture and demonstrative series for experienced investigative personnel, consisting of instruction on crime scene search techniques and the preservation of physical evidence. These lectures also involve detailed instruction in NAA capabilities and limitations, as well as practice in scientific sample collection, handling and storage techniques.

The third level consists of a continuing series of informal discussions with crime laboratory staff members. University of Missouri staff members from the Law Enforcement Extension and the Research Reactor Facility periodically visit all major crime laboratories in Missouri to discuss the NAA program in depth. These informal sessions place particular emphasis on deciding which analytical techniques are most appropriate for a particular problem. Since for many types of materials existing methods are as good as NAA if not better, the areas where NAA has its most significant applications are emphasized. In addition, the current developments in the Missouri service program with regard to specific types of materials are covered.

#### b. Research and Development

The Reactor Facility staff attempts to employ procedures for forensic applications of NAA which have already been developed and proven in the field. Development work is necessary to adapt a technique of NAA to the particular facilities available and to acquire a background of statistical data. The staff must become intimately familiar with any technique used for analysis of evidentiary materials as well as with the expected variations to be found in a particular type of specimen. This familiarity insures proper presentation of data at trial. Furthermore, efforts are made to develop new applications and to improve and extend existing techniques.

#### c. Service

The main objective of this program is to provide a routine physical evidence characterization service to Missouri law enforcement agencies and expert witness testimony upon request. At this time the Reactor Facility

is set up to analyze on a routine basis gunshot residue, hair, paint, fibers, and substances that may contain arsenic. Techniques and procedures are being developed to analyze safe insulation, soil and glass. It is possible that paper and other items could be analyzed in some cases. Gunshot residue collection kits are available from the Reactor Facility to Missouri law enforcement agencies at no charge.

It is suggested that law enforcement agencies in the Kansas City and St. Louis areas channel evidence to be analyzed to the Reactor Facility through their respective crime laboratories; those in Southeast Missouri through the regional crime laboratory in Cape Girardeau; and those in Central Missouri through the Highway Patrol crime laboratory. Those in other areas of Missouri may work directly with the Reactor Facility or through the Highway Patrol troop in their area.

The training portion of this program aids the service portion in light of the fact that proper collection of appropriate samples is necessary for success of the program. Also, the training sessions provide investigative and laboratory personnel with enough background information to distinguish those samples which are appropriate for NAA from those which are not or which might be better analyzed by other methods.

## 2. Other Forensic NAA Services

A number of nuclear laboratories provide NAA services, using the mail for shipment of samples where necessary. Some of these include Gulf General Atomic, Inc., San Diego, California; Union Carbide, Nuclear Division, Tuxedo Park, New York; and Western New York Nuclear Research Center, Buffalo, New York. By using services such as these, criminalists are able to take advantage of the NAA process without having to buy their own equipment, thus overcoming the cost obstacle of NAA for many.<sup>99</sup>

Gulf General Atomic now offers a non-profit Forensic Activation Analysis Service which is available to all law enforcement agencies and defense counsels.<sup>100</sup> Through this service NAA tests have been conducted on evidence samples used in a number of criminal cases. In some cases, the Gulf General Atomic radiochemists who performed the analyses presented the results in court. As another part of this service, Gulf General Atomic provides a special kit for collecting gunshot residue samples from the hands of suspects in shooting cases. Many law enforcement agencies across the country have obtained these kits.<sup>101</sup>

## VI. CONCLUSION

NAA has considerable potential for certain forensic applications. It is an established method of elemental analysis and, if properly applied, can be a useful tool for the examination of a wide variety of evidentiary materials. Indeed, there have been increasing applications of NAA in criminal cases, and the method is gaining general acceptance in both state and federal courts.

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99. Watkins 127.

100. APPLICATIONS OF NAA Ann. Rep. 93-94; Watkins 29 (Supp. 1971).

101. Watkins 30 (Supp. 1971).

NAA is ideally suited for applications requiring high sensitivity and non-destructiveness. The ability of the NAA method to accurately detect extremely low concentrations of trace elements in very small samples enables it to solve many problems of identification that have been impossible to solve by conventional methods. Furthermore, since the method is usually non-destructive, evidence can be preserved for other tests or future use in court. However, in solving many problems different methods may be better and more useful to the analytical chemist. In determining what method of evidentiary analysis is best suited for use in court, there must be continual evaluation of the NAA technique and a critical appraisal of its capabilities and limitations.

Although NAA has progressed in importance and usefulness as a method of scientific crime investigation, it is not yet extensively used by forensic chemists and law enforcement agencies. There are a number of reasons for this. First, the method and its capabilities are still widely unknown to police, criminalists and lawyers. Furthermore, the high costs of the nuclear reactor and other equipment needed, combined with the need for highly specialized personnel to perform the sophisticated tests, makes it impracticable for state and local law enforcement agencies to set up their own activation analysis facilities. Lastly, it should again be emphasized that often other methods are cheaper, simpler and better suited for forensic chemists to analyze their samples.

One way to provide greater use of NAA is to expand the use of state supported institutions such as the University of Missouri's forensic NAA service at the Research Reactor Facility. Such institutions have available both the expensive equipment and highly specialized personnel required for NAA.

Other technological advances are helping to make NAA a better and more practicable method. Although expensive nuclear reactors have been the primary radiation sources used for NAA tests, substantial progress has been made in the development of other effective neutron sources which are far less expensive than reactors. Although these newer neutron sources will provide lower neutron fluxes than reactors, and thus provide lower sensitivity, advances in modern electronics are simultaneously providing better gamma detection and measuring equipment.

In forensic science NAA shows promise of being a useful investigative tool, but it is not a solution to all problems and oversell of the method must be guarded against. A prudent approach is needed by those using the method and by the courts. However, it is clear that if used properly and not abused, in certain situations NAA can provide a high degree of sophistication to the ascertainment of truth in our courts.

WEBB R. GILMORE