J Forensic Sci, Jul. 1974, Vol. 19, No. 3

J. M. Stevens,[1] *B.A. and Harold Messler,*[1] *B.S.*

The Trace Metal Detection Technique (TMDT): A Report Outlining a Procedure for Photographing Results in Color, and Some Factors Influencing the Results in Controlled Laboratory Tests

When the investigation of a crime involving the use of a firearm leads to the apprehension of one or more suspects, the question inevitably arises as to whether or not some connection between the weapon involved and an individual suspect can be established. Frequently at this point the question becomes a problem for the forensic scientist, and his ability to demonstrate a physical link between suspect and weapon may be of vital consequence to the successful completion of the investigation and subsequent prosecution of the suspect. However, a glaring disparity becomes evident when one considers the elemental importance of this problem, and the paucity of valid methods available to the forensic scientist which he may use to solve it.

Despite its continued prosperity in countless television and movie scripts, the paraffin test is probably still administered in very few, if any, forensic laboratories. In striking contrast to the paraffin test is the considerably more reliable, albeit highly sophisticated, technique of neutron activation analysis (NAA) for the detection and quantitation of trace elements commonly found in cartridge primers (notably barium and antimony). The rapidly increasing utilization of this extremely sensitive tool seems justified, and its greatest contributions to date in forensic applications have centered around gunshot residue analysis.

While NAA is undeniably one of the most sensitive, reliable, and sophisticated methods available as yet for showing that a suspect has recently fired a gun, it obviously can be of no value in crimes where a gun was merely displayed and not fired. Even in cases of violent crime where a gun has been discharged, the very sophistication of NAA may preclude its utilization in any but the most open-and-shut cases. Investigating officers have only a few hours after detaining a suspect in which to establish the probable cause necessary for obtaining a warrant charging the suspect with a crime; however, the results of NAA of swabs taken from the hands of a suspect may be several weeks in coming. If investigators need to narrow a field of several suspects to one or two most likely to be involved, they need information immediately in order to avoid much wasted effort pursuing less likely prospects. Clearly, in such cases some more expedient or versatile approach is desirable.

Received for publication 8 Feb. 1973; revised manuscript received 24 Sept. 1973; accepted for publication 10 Dec. 1973.

[1] Criminalists II, Laboratory Division, St. Louis Metropolitan Police Department, 1200 Clark St., St. Louis, Mo. 63103.

In the latter part of 1970, a pamphlet entitled "Trace Metal Detection Technique in Law Enforcement" [1] was distributed to forensic laboratories throughout the country by the National Institute of Law Enforcement and Criminal Justice. This publication describes a simple and expedient technique, using readily available materials, which allows a trained specialist to determine whether an individual has recently been in contact with a particular metal object. It is noteworthy that the test discloses contact with metal *objects*, and therefore has some potential in the investigation not only of crimes involving guns but also, theoretically, in crimes where other types of metallic implements may have been used, such as burglaries, assaults, etc.

Basically the procedure involves applying a 0.1–0.2 percent solution of 8-hydroxyquinoline in alcohol to the subject's hands, either by immersion or by spraying from an entirely metal-free system, and allowing them to air-dry. The 8-hydroxyquinoline undergoes a chelating reaction with various metallic ions present on the skin's surface to form oxinate complexes. When viewed under shortwave ultraviolet light, these complexes either emit various fluorescent colors or cause a quenching of the light yellow background fluorescence imparted to treated areas of the skin by the solution. The general reaction involved is shown in Fig. 1, where M is one equivalent of metal. The fluorescent color observed depends upon the particular metal present, with different metals producing different colors. When viewed under ultraviolet light any metallic residue left on the hands after handling a particular object would appear as various colored patterns outlining those areas of the hand which were in contact with the object. Each of various objects, held in the usual manner for its intended use, would produce a distinctive pattern which, after gaining sufficient experience in observing such patterns, could be recognized and identified by the observer. The color of the pattern gives information concerning the metallic composition of the object, with the position, shape, and extent of the pattern indicating the shape of the object.

Because of the obvious investigative potential of such a technique, early in 1971 this laboratory undertook its own exploration of the procedure, with the purpose of investigating the reliability of the trace metal detection technique (TMDT) described in the pamphlet. A program of experimentation was set up to serve the dual purposes of familiarizing each of our criminalists with the technique and providing us with the beginnings of a photographic catalog of the patterns characteristically produced on the hands by various types of handguns and tools. As repeatedly emphasized in the original pamphlet, the successful employment of the technique hinges upon the acquisition of considerable personal experience, augmented by the accumulation of an extensive photographic file of patterns characteristic of as many different weapons and tools as possible.

As our investigation of the technique progressed, several problems were encountered and a number of observations regarding various aspects of the technique were made. A discussion of these problems and the procedures employed to counter them, as well as personal observations, follows.

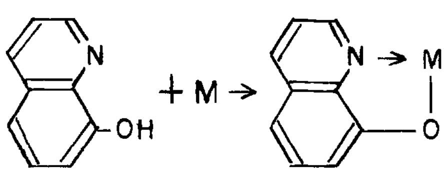

FIG. 1—*General reaction for the chelation of 8-hydroxyquinoline.*

Experimental Procedures

Hand Preparations

Two litres of a 0.15 percent solution of 8-hydroxyquinoline in isopropanol were prepared in a nalgene cannister with a tight fitting lid. It was found that this solution could be used for multiple immersions and, consequently, it was exchanged for fresh solution only after every two or three weeks (or approximately 40–50 immersions), when discoloration of the solution became pronounced. No interference from metallic residue left by previous immersions was noted within this time period. Prior to application of the solution by immersing the hands up to the wrist, each subject was instructed to scrub his hands vigorously. At least one hour elapsed following scrubbing. At the end of this time each subject was provided with a handgun supplied by our Firearms Identification Section. For the sake of expediency the subjects frequently were given a gun or tool for each hand, to be held simultaneously. When a gun was used the subject was instructed to hold the gun in the normal fashion for a period of three to five minutes, being sure to squeeze the trigger and cock the hammer several times. The guns were then set aside and the subject resumed his normal business for a period of time ranging from five minutes to one hour. Following this variable time period, the subject immersed his hands in the solution for three seconds, removed them, and dried them under a hair drier. The subject was then taken into a completely blackened room and his hands were photographed under the appropriate conditions described later. Both Caucasian and Negro personnel from within the St. Louis Police Department were solicited as subjects, the majority of them members of the laboratory staff.

The only variations of this procedure occurred on the few occasions when we were requested to perform the test on deceased individuals at the city morgue, in conjunction with investigations by members of our Homicide Division of cases involving alleged suicides. In these cases the hands were sprayed with the solution from a glass and plastic chromatographic sprayer, rather than using the immersion method. The hand washing was eliminated, as it would be in any actual crime investigation.

Photographic Techniques and Influencing Factors

Our early efforts quickly disclosed the inadequacy of relying solely upon black-and-white photographs for documentation of the patterns observed from various types of handguns or tools. No particular difficulties were encountered in obtaining photographs of good contrast using Polaroid black-and-white films, whenever the gun or tool involved was manufactured of good quality steel. Here the patterns were invariably of a dark purplish black color resulting from the quenching of the yellow background fluorescence imparted by the TMDT solution. Test results were photographed using either a Polaroid MP-3 or CU-5 camera. When using the CU-5, a Polaroid 4 by 5-in. back was attached, as well as a ½:1 framing kit and a 5-in. lens. Other pertinent data are given in Table 1.

TABLE 1—*Photographic data for black-and-white Polaroid film records of TMDT results.*

Camera	Film Type	Aperture	Exposure, s	Illumination Source	Lamp:Subject Distance, in.	Filter
MP-3	57	f5.6	2	1 UVS-11	4	2A
CU-5[a]	57	f4.7	2	1 UVS-11	6	2A

[a] The CU-5 camera was equipped with a 4 by 5-in. film back, a 5-in. lens, and a ½:1 framing kit.

Illumination was provided by a single model UVS-11 Mineralight®, mounted 6 in. above the subject at an angle of 30 deg.

It was found, however, that handguns of lesser quality, manufactured from various grades of steel or aluminum alloys (that is, "pot metals"), produced patterns which were intensely yellow and contrasted sharply with the pale yellow of the background color. Furthermore, it was not uncommon to find guns which, although made primarily of these pot metals, had grips which were secured by a screw of high quality steel, and perhaps a hammer or trigger of some intermediate grade alloy which produced a brown or tan pattern. Of course, attempts to faithfully record these observations on black-and-white film resulted in a disastrous loss of much potentially diagnostic information, underscoring the need to discover a procedure suitable for use with color film.

All attempts to use Polaroid color film for this purpose failed dismally, as might be expected since it has a rated ASA equivalency of only 75–80. This indicated to us that both light intensity and film speed would need to be greatly increased if exposure times were to be kept reasonable. The increased light intensity was accomplished by mounting dual model UVS-54 shortwave lamps at a distance of 6 in. from the subject. Each of these lamps produces shortwave ultraviolet illumination with an intensity rated at 680 $\mu W/cm^2$, measured at a distance of 6 in. and a wavelength of 253.7 nm. All of the ultraviolet sources used in this project were supplied by Ultra Violet Products, Inc., of San Gabriel, Calif. For purposes of comparison, the rated intensity of each of the lamps used is given in Table 2.

TABLE 2—*Intensities of various ultraviolet light sources.*

Lamp Model	Intensity at 6 in. (λ = 253.7 nm), $\mu W/cm^2$
UVS-11	400
UVS-54	680
C-81	1200
S-68	1920

To obtain the maximum film speed, we selected Kodak High Speed Ektachrome Film, Daylight Type, which we processed ourselves, using a modification of Kodak's E-4 process which resulted in "pushing" the film to an ASA of 640. This procedure was adopted following a search of the literature on ultraviolet photography [*2,3*] and correspondence with several experts in the field. The modification in the developing process consisted of leaving the film in the first developer solution for ten minutes. The camera used was an Exakta 35-mm SLR, mounted with a 1.9/50 lens. It was necessary to place over the lens a Wratten No. 2C barrier filter to screen out any reflected UV light reaching the camera, and also a Wratten No. 6 color correction filter. Both filters were of the gelatin type, preferred because they have less bulk than glass filters and are not as breakable. In mounting these filters, it is absolutely essential that they be placed in front of the lens with the No. 6 nearest to the lens. Mounting the filter pack in reverse order will result in a fluorescence of the filters themselves, possibly causing overexposure and fogging of the film. Lens-to-subject distance was maintained at 19 in. throughout, and each photo received an 8-s exposure at f5.6.

As a special precaution, no subject was allowed to accumulate more than four minutes of total exposure to the UVS-54 lamps within a 48-h period, in order to minimize any possible radiation hazard. All participants wore protective goggles or glasses during exposure. These measures provided a wide safety margin, and no problems of erythema or actinic keratitis were encountered at any time.

As a parallel study, we sought to evaluate the effectiveness of several different ultraviolet light sources in decreasing the required exposure time. To this end, a series of photos were taken with each of the available sources, keeping all data the same as previously given, but altering the exposure times. Consequently, it was found that by using dual model S-68 lamps we could reduce the exposure to a range of 4–6 s, depending upon pattern color and intensity. However, it is felt that the 8-s exposures obtained by using the model UVS-54s are not unreasonable, especially when weighed against the disadvantages associated with the model S-68s (for example, increased bulk, awkwardness, higher purchase price, and possible radiation hazard). By cutting the aperture to f2.8, adequate pictures were obtained using the dual UVS-11s and a 16-s exposure. With a model C-5 Chromatoview® cabinet, the single model C-81 lamp will suffice when held 6–8 in. from the subject in conjunction with an 8-s exposure at f4.

The procedures outlined proved to be satisfactory, with the resulting color and black-and-white photographs providing an accurate and permanent record of our visual observations concerning the TMDT patterns of each gun and tool used. The acquisition of a catalog or file of TMDT patterns associated with many different guns and tools had begun in earnest.

Results and Discussion

A prime objective of this laboratory's use of TMDT has been achieved. Administration of the TMDT may disclose the presence of metallic residues on the hands of a suspect in patterns attributable to contact with specific types of handguns or tools. The development of a procedure for taking color photographs which accurately record these patterns was highly desirable, for it enables the criminalist not only to maintain and expand a catalog of such gun and tool "signatures," but also to document his observations in connection with a particular examination for possible future court presentation. The frailty of human memory necessitates the collection of a large number of such photographs, which are essential to the development of expertise in recognizing and interpreting the significance of these characteristic patterns. Nevertheless, this laboratory is convinced that when called upon to administer TMDT in connection with an investigation, it is far better, whenever possible, to have the actual weapon involved available in order to directly compare any patterns observed on the suspect and the pattern known to result from handling that particular gun. There is always the possibility that the particular gun or tool used in the commission of a crime might impart a pattern sufficiently unique as to make a positive connection between the instrument and suspect possible. In any event, we strongly suggest that prospective users of the technique give some consideration to establishing a policy of routinely refusing requests to perform the examination unless the gun is available for direct comparison, at least until the observer has acquired considerable experience and familiarity with the various patterns.

Efforts made by this laboratory directed toward accumulating both experience and photographic data soon led to several observations of passing interest concerning TMDT, and some factors which seem to exert an influence on the quality of the resultant patterns.

Pattern Intensity versus Skin Condition

One early discovery was that the intensity of the pattern produced by a particular gun varied considerably. This variance was noted especially between individual subjects, but occasionally was encountered in successive processings involving the same individual handling the same gun, in spite of efforts to keep all of the variables involved constant between individuals and between testings. Some individuals always seemed to be good subjects for the tests, while others constantly displayed indistinct or moderately intense patterns. Since even the "good reactors," as we began to label them, sometimes showed progressively less distinct patterns the more they were used in a given session, we began to suspect that some factor not touched upon in the original pamphlet was involved in the reaction between the metallic residue and the 8-hydroxyquinoline. While theorizing as to whether this influence might be of a physiological or mechanical nature, it was recognized that the condition of the subject's skin at any particular time offered a possibility encompassing both. We have consequently concluded that the presence of a normal complement of perspiration is mandatory for the successful application of the technique. This theory is in agreement with statements made by Dr. Phillip W. West while participating in the Symposium on Trace Analysis held at the New York Academy of Medicine in 1955. He reported that the chelating reaction is greatly enhanced when carried out on human skin as a host media, with gelatin being the media of second choice [*4*]. This was why we allowed at least one hour for the replenishment of perspiration following any hand washing activity, before attempting to use an individual for TMDT. Of course, individuals vary considerably in how freely they perspire, and this could explain the differences noted in subject suitability for the procedure.

The reaction's dependence upon perspiration was further indicated as a result of our efforts, for the sake of expediency, to produce the fluorescent patterns on filter paper or cloth. At first we were unable to achieve any hint of a pattern on either of these materials. However, it was discovered that quite good results were obtainable if the material were pretreated by immersing in a solution of normal saline containing a small amount of gelatin and allowed to dry to the point of slight dampness. The gun or tool was then placed on the damp paper or cloth for approximately 30 min (the time may be shortened considerably by the addition of pressure on the object), the material was allowed to dry completely, and then the test solution was applied.

Effects of Object Surface Condition on TMDT Patterns

Our experiences have also disclosed that the quality of the fluorescent patterns observable on a subject's hands, following the application of the test solution, is influenced greatly by factors concerning the surface conditions of the object material. Indeed, some guns failed to produce any patterns under any conditions. This might be expected, since guns differ greatly in their metallic composition and some metals or alloys simply do not react with the 8-hydroxyquinoline. The existence of a chrome or nickel plating, for instance, frequently coincided with a lack of any resulting pattern, although in a few cases weak patterns were detected. But one would expect that all guns of the same manufacture would produce patterns of equal quality. Such was not the case, however. Of particular interest was our discovery that in several instances application of the test solution resulted in the immediate disclosure of a pattern which was quite discernible in ordinary white light. When viewed under ultraviolet light these patterns were invariably the most intense observed. It is our present belief that all of these latter observations are associated with differences in the condition of the surface metals of the guns involved. Grasping a well-used, older service revolver of a police officer, for instance, generally resulted in the formation of a readily distinguishable TMDT pattern when viewed under ultraviolet light. But when a revolver of similar make and model, but of significantly newer vintage, was used, application of the solution to the subject's hands frequently failed to disclose a pattern. A possible explanation could very well be the breaking down (at least partially) of the bluing on the older gun. Gun bluing involves the oxidation of the weapon's surface

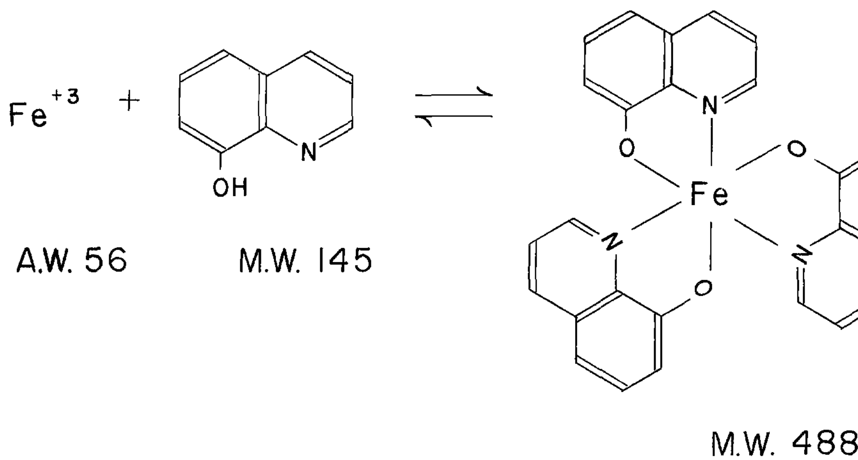

FIG. 2—*Reaction of ferric ion with 8-hydroxyquinoline.*

metal. The chelation reaction requires that the metallic residue involved be in the form of particles capable of being readily ionized. The iron oxide is more resistant to ionization, and therefore forms a protective barrier impeding the reaction. In all cases where a pattern clearly visible in white light resulted, the guns involved were invariably older ones which had been handled infrequently, if at all, over a period of several years. In most cases, these were taken from the laboratory's display collection. Such guns have been relatively undisturbed, except for wide fluctuations of temperature and humidity. They predictably had a very dull finish and felt dirty or dusty to the touch, indicating the accumulation of relatively large amounts of loosened particles of metal. The general reaction given earlier, as applied to iron, is shown in Fig. 2. The chelate formed with the majority of metals is a yellow precipitate, but that formed with iron is black. It seems conceivable that a quantity of this black precipitate could be too small to detect with the unaided eye in white light, but still be sufficient to cause the quenching of the background fluorescence under ultraviolet light. Larger amounts of this precipitate, however, would eventually become visible in white light, and these older, weathered guns inevitably deposited a heavier residue of metal particles on the hands.

It is emphasized that these observations, and conjectures regarding their etiology, at this point are presented simply as conjectures or observations. The demands of everyday criminalistics have not as yet permitted the authors to actively pursue further elucidation of the mechanics involved—a situation universally familiar to forensic laboratories. But these observations do serve to illustrate the need for more research concerning TMDT, and suggest some possible avenues of further exploration. We feel that the technique holds much promise in forensic investigation, but that much more work is required before its full potential can be realized. This paper is submitted in the hope of stirring some interest in the technique and of stimulating additional work with it.

Summary

A procedure for obtaining color photographs which faithfully record the observed results of the application of the trace metal detection technique is presented. Methods for the black and white photographing of these observations with Polaroid film are outlined,

as is the need for such documentation. The observed influence of several factors, such as perspiration, metallic composition, and the condition of gun bluings and platings, on TMDT findings is stated and discussed. Finally, the role of the TMDT in forensic investigations and the current state of development and utilization of the technique is considered briefly.

Acknowledgments

Acknowledgment is made of the assistance of Ultra-Violet Products, Inc., of San Gabriel, Calif., who made the use of a variety of ultraviolet sources available to us on a loan basis.

The authors are further indebted to the Crime Laboratory Advisory Committee of the St. Louis Chapter of the American Chemical Society for their advice and guidance.

References

[*1*] "Trace Metal Detection Technique in Law Enforcement," Pamphlet No. 71-1, National Institute of Law Enforcement and Criminal Justice, LEAA, Washington, D.C., 1970.

[*2*] "Ultraviolet and Fluorescence Photography," Kodak Technical Publication M-27, Eastman Kodak Co., Rochester, N.Y., 1968.

[*3*] "A Simplified Method for Chromatographic 35mm Photography. The Dart," Ultra-Violet Products, Inc., San Gabriel, Calif., 1968.

[*4*] Yoe, John H. and Koch, Henry J., Jr., *Trace Analysis*, John Wiley & Sons, N.Y., 1955, p. 186.

Laboratory Division
St. Louis Metropolitan Police Dept.
1200 Clark St.
St. Louis, Mo. 63103