# Distance Determination

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# Distance Determination

## 1 Introduction

This procedure is designed for the evaluation and examination of a suspected bullet hole or similar damage as a basis of estimating muzzle-to-target distances. Distance determination examinations includes the evaluation of physical effects, shot patterns, patterns of nitrite residues, and presence of lead residues around a suspected bullet hole. Such holes of patterns may be on clothing items, furniture, bedding, and wallboard.

## 2 Scope

This procedure applies to Firearms/Toolmarks Discipline (FTD) personnel or authorized personnel when conducting forensic examinations in the FTD.

## 3 Equipment

- Equipment
  - Microscope (stereozoom)
  - Measuring equipment
  - General purpose oven
  - Heat press
- Material
  - General laboratory supplies
  - Known exemplars
  - Personal protective equipment (PPE)
  - Target backing material
  - Cheesecloth
  - Ammunition
  - Chemical reagents and test media:
    - 15% Acetic Acid Solution
    - 2% Potassium Hydroxide (KOH) in Ethanol
    - 2.8 pH Buffer Solution
    - 5% Hydrochloric Acid Solution
    - Nitrite Test Swabs
    - Photographic Paper or similar paper media
    - Sodium Rhodizonate Solution

## 4 Standards and Controls

Standards are handled as follows:

- Known-distance test patterns produced from a known firearm and ammunition combination are used as standards for evaluating distance determination.
  - Exemplars will be treated as secondary evidence in accordance with FTD-121.

Controls are handled as follows:

- A lead bullet is used as the positive control for lead residues testing.

    - A lead bullet will be wiped across a piece of test material and the material then processed for the expect blue-violet reaction.
    - The performance check will be recorded in the FTD Worksheet.
- A nitrite test swab is used as the positive control for nitrite residues testing.
    - To ensure the photographic paper is functioning properly, test the four corners of the emulsion-coated side with a positive control.
        - This is accomplished by saturating a nitrite test swab in a small amount of 15% acetic acid solution and dabbing the four corners of the paper.
        - An orange color should appear at each corner, confirming sensitivity.
        - The performance check result will be recorded in the FTD-050 Chemical Reagent Log.
    - For a negative control, use a clean, non-nitrite treated acetic acid-saturated test swabs.
        - Ensure this test follows the positive control test, and that there is sufficient physical separation between test marks to preclude bleeding from one mark to the other.
        - The performance check result will be recorded in the FTD-050 Chemical Reagent Log.
- Recently purchased or acquired supplies that have direct contact with chemically processed items, will have a negative control performed and recorded in the FTD Worksheet.

## 5 PROCEDURE

### 5.1 GSR Examination Workflow

The Gunshot Residues Examination Workflow outlines the procedural sequence of the visual, microscopic, and subsequent chemical examinations.

A. Visual and Microscopic Examinations
B. Chemical Examinations
    1. Nitrites residues
        i. Total Nitrite Visualization (TNV)
            a. Note: the Total Nitrite Visualization Test always precedes the Sodium Rhodizonate Test.
        ii. Modified TNV (mTNV)
    2. Lead residues
        i. Sodium Rhodizonate Test (SoRho)
            a. Note: the Sodium Rhodizonate Test has the potential to chemically interfere with the results of the TNV test.
            b. Direct application on light-colored materials
            c. Transfer methods for dark-colored materials
                1. Bashinski transfer
                2. Blotting transfer

## 5.2 Visual and Microscopic Examination

A. It should be noted that the initial examination is in regard to the observable physical characteristics and microscopic examination for residues which may be present.
B. Initially, a visual examination is performed to determine the presence of gunshot residues. A sketch or photograph is taken to record the item being examined and the relative position of hole(s) or gunshot residues.
    1. When visually examining clothing having a dark color or pattern, the use of infrared photographs can assist in the detection of gunshot residues.
C. Microscopic examinations are performed using a stereozoom binocular microscope with appropriate lighting. Various types of relevant physical effects and residues may include:
    1. Indicative of/consistent with the discharge of a firearm:
        i. Vaporous lead (smoke).
        ii. Particulate lead shavings or solidified droplets.
        iii. Unburned gunpowder.
        iv. Melted, adhering gunpowder.
        v. Soot
    2. Indicative of/consistent with the passage of a bullet:
        i. A hole in an item.
        ii. A visible ring around the perimeter of the hole (bullet wipe).
    3. Indicative of/consistent with a contact shot:
        i. Ripping, tearing.
        ii. Burning, singeing.
        iii. Melted synthetic fibers.
        iv. Heavy vaporous lead residues (smoke).

## 5.3 Preparation of Reagents and Test Media

A. If a chemical reagent or test media must be prepared before an examination, the FTD-050 Chemical Reagent Log will be used and the following information will be recorded:
    1. FTU lot number
    2. Preparer
    3. Date
    4. Parent chemical (lot number)
    5. FBI Laboratory serial number
    6. Performance check result
B. The FTU lot number for reagents and test media used during examinations will be recorded in the FTD Worksheet.

## 5.4 Chemical Examinations

After completion of the microscopic examinations, certain chemically specific, chromophoric tests are conducted for various types of gunshot residues.

### *5.4.1 Nitrite Residues*

The initial test, TNV or mTNV *for Nitrite Residues*, is directed toward the detection of deposits of nitrite compounds from burned or partially burned gunpowder around a suspected bullet hole or patterns of suspected shot pellet holes.

Determine the condition of the evidence item to decide if the traditional TNV or modified TNV procedure will be used.

A. Traditional TNV is selected when a transparent-adhesive lifter will be used.
B. Modified TNV is selected when the procedure is done directly on the evidence item and no adhesive is required.

#### *5.4.1.1 Traditional Total Nitrite Pattern Visualization (TNV)*

The TNV test includes transfer of nitrites from an evidence item to an adhesive lifter. This can be applied to damaged, thick, or otherwise non-porous material.

A. Place a transparent adhesive film, adhesive side down, over the questioned area.
B. Press the adhesive so it adheres to the questioned area.
C. Use a sharpie/pen to indicate on the adhesive film objects such as seams, buttons, suspected bullet holes, pockets, rips, tears, and cuts for future reference.
D. Peel the adhesive away and place it, adhesive side up, on butcher paper.
    1. Tape the corners of the adhesive down.
E. Spray the adhesive with 2% Potassium Hydroxide (KOH) in ethanol.
    1. Uniformly dampen the adhesive surface with a 2% KOH from a spray bottle.
F. Place the butcher paper with the adhesive on it into a general-purpose oven for ten minutes at 100°C.
    1. Remove from the oven after the ten minutes is over.
G. Wipe the emulsion/treated side of the photographic paper with a piece of cheesecloth saturated with 15% acetic acid solution, removing excess solution.
    1. Lightly apply the solution to the entire surface with cheesecloth.
    2. Too much acetic acid solution will cause indistinct or hazy results due to pigment migration.
H. Immediately place the adhesive film, adhesive side down, onto the treated side of the photographic paper.
    1. Prior to placing in the heat press, place a piece of material such as cheesecloth between the piece of adhesive and heat press.
    2. Failure to attach a piece of material will likely result in the adhesive sticking to the heat press.
I. Place in the heat press for 1 minute at 70-90°C.
    1. See MPress Owner's Manual for instructions.
J. Remove from the heat press.
K. Any orange indications on the photographic paper are the result of a chromophoric reaction specific for the presence of nitrite residues.
L. When dry, the photographic paper will be marked appropriately.
M. Processed photographic paper will be treated as secondary evidence in accordance with section 3.4 of FTD-121.

#### *5.4.1.2 Modified Total Nitrite Visualization (mTNV)*

A. Directly spray the questioned area with the 2% KOH in ethanol solution.
B. Place the evidence item into the general-purpose oven for ten minutes at 100°C.
    1. Remove from the oven after the ten minutes is over.
C. Wipe the emulsion/treated side of the photographic paper with a piece of cheesecloth saturated with 15% acetic acid solution.
    1. Lightly apply the solution to the entire surface.
    2. Too much will cause indistinct or hazy results due to pigment migration.
D. Immediately place the questioned area down onto the treated side of the photographic paper.
    1. Index the photographic paper relative to the garment or other item to indicate the location of such things as suspected bullet holes, seams, buttons, buttonholes, pockets, rips, and tears. Indexing in pencil is preferable since ink may bleed during the application of reagents.
    2. Prior to placing in the heat press, place a piece of material such as cheesecloth between the evidence item and heat press to avoid burning of the evidence item.
E. Place in the heat press for 1 minute at 70-90°C.
F. Remove from the heat press.
G. Any orange indications on the photographic paper are the result of a chromophoric reaction specific for the presence of nitrite residues.
H. When dry, the photographic paper will be marked appropriately.
I. Processed photographic paper will be treated as secondary evidence in accordance with section 3.4 of FTD-121.

### *5.4.2 Lead Residues*

*SoRho Test for Lead Residues* is directed toward the detection of any type of lead residue which might be present. This would include vaporous lead (smoke) usually associated with closer ranges, particulate lead and “bullet wipe,” a ring-shaped deposition often found around the perimeter of a bullet hole.

#### *5.4.2.1 Direct Application of the SoRho Test*

A. Spray the questioned area on the evidence item with the saturated solution of sodium rhodizonate.
B. Spray the same questioned area with the tartaric acid/sodium bitartrate buffer solution.
    1. This solution will eliminate the general yellow background color caused by the sodium rhodizonate and will establish a local pH of 2.8, turning any lead, as well as other metals that may be present, a pink color.
C. Spray the same questioned area with the 5% hydrochloric acid solution.
D. The presence of lead is specifically determined wherever the previous pink color fades out and leaves a blue-violet color in its place; this indicates lead.
    1. Be very aware that a positive (blue-violet) result may abruptly fade.
    2. Note the results or photograph immediately after applying the dilute hydrochloric acid solution.

*5.4.2.2 Bashinski Transfer of the SoRho Test*

A. Place a piece of filter paper over the appropriate area of the questioned item.
B. Index the filter paper relative to the garment or other item to indicate the location of such things as suspected bullet holes, seams, buttons, buttonholes, pockets, rips, and tears. Indexing in pencil is preferable since ink may bleed during the application of reagents.
C. Uniformly dampen the filter paper on the questioned item by spraying with a 15% solution of glacial acetic acid from a spray bottle.
D. Cover the dampened filter paper with several layers of dry butcher paper.
E. Place in the heat press for 1 minute at 70-90$^{o}$C or until dry.
F. Remove the filter paper, which was in direct contact with the evidence item, and process it using the section 5.4.2.1. Note that any positive (blue-violet) indications are a mirror image of the deposition on the questioned item.
G. Prompt note-taking is essential in that sometimes the color can fade rapidly and unpredictably.
H. When dry, the filter paper will be marked appropriately.
I. Processed filter paper will be treated as secondary evidence in accordance with section 3.4 of FTD-121.

*5.4.2.3 Blotting Transfer of the SoRho Test*

A. Process the questioned item by following section 5.4.2.1.
B. Blot the appropriate area of the questioned item using untreated filter paper.
C. Note any positive results. Such transfers usually reflect positive results which are very vague and indistinct in form.
D. When dry, the filter paper will be marked appropriately.
E. Processed filter paper will be treated as secondary evidence in accordance with section 3.4 of FTD-121.

## 5.5 Interpretation of Results

*5.5.1 Contact Shot*

A contact shot is based on the presence of characteristic ripping and tearing of an item, the burning and singeing of cloth, the melting of synthetic fibers, and the heavy vaporous lead (smoke) deposits around the suspected bullet hole.

*5.5.2 Nitrite Residues*

With increases in muzzle-to-target distances, patterns of detectable nitrite residues around a suspect bullet hole vary in size and density. When a pattern of nitrite deposits is found, it is possible to reproduce this pattern using the submitted firearm and ammunition in combination. When only scattered nitrite residues are found, it is possible to find the maximum distance to which such residues are deposited, using the submitted firearm and ammunition in combination.

### *5.5.3 Lead Residues*

#### *5.5.3.1 Vaporous Lead Residues*

Vaporous lead deposits are characteristically deposited at close ranges and are chemically detectable utilizing the SoRho Test. Such residues are produced to a particular maximum distance, which is determined utilizing the suspect firearm and ammunition in known-distance tests.

#### *5.5.3.2 Particulate Lead Residues and Bullet Wipe*

Lead bullet wipe is consistent with the passage of a bullet. Particulate lead residues are consistent with the discharge of a firearm, and neither can be used to determine distance.

## 5.6 Known-Distance Test Patterns

A. When reproducing residue patterns detected on an evidence item, it is essential the suspect firearm and ammunition, or similar, be used to produce test patterns.
    1. Residue patterns will vary with changes in ammunition, barrel length, caliber, and powder charge.
B. For the majority of situations, white cotton twill cloth is suitable as a test pattern material.
    1. However, there may be instances where the characteristics of the evidence item are unusual enough to preclude meaningful test patterns with the cotton twill cloth.
        i. In such cases, it may be necessary to duplicate the evidence material, or to utilize a portion of the evidence item for firing known-distance tests.
C. When reproducing test patterns, it is appropriate to fire at known-distances that will produce test patterns both smaller and larger than the residues detected on an evidence item.
    1. Using the known-distance test patterns, a “bracket” is established to include the evidence residue pattern.
        i. Such a “bracket” should be wide enough, typically 1 foot in width when outside near contact/contact, to account for differences expected in commercially manufactured ammunition and variations normally expected from shot-to-shot.
    2. A reported “bracket” will be:
        i. verified by a second qualified examiner and
        ii. supported by known-distance test patterns produced at the same distances reported.
D. When nitrite residues are found without a pattern, it may be necessary to find the maximum distance for gunpowder residues that are projected from a firearm. The procedure in these instances is to gather data that can be used to establish the distance at which the nitrite residue is often found, and the distance at which it is rarely found in known-distance tests.

1. This forms a maximum distance situation for a specific firearm and ammunition combination.

## 5.7 Shot Pattern Examinations

### *5.7.1 Microscopic and Visual Examination*

A. Although shot patterns in victim garments and other objects are normally microscopically examined and chemically processed to detect residues such as nitrite compounds, and lead due to 'pellet wipe', the basis for most distance determinations is the size of the shot pattern and its reproduction. Patterns produced by shot pellets will be elongated in some cases since an angle other than 90 degrees existed between the barrel of the weapon and the area of impact. In this situation, the narrower dimension is the significant dimension as a basis for comparison with the size of known-distance patterns.
B. It is also important to note that a shot pattern is not necessarily the product of a shotgun having been fired, at least in the case of the smaller shot sizes. Handgun 'snake' loads are common in a variety of calibers. In addition, during the microscopic examination it is possible that fine plastic particulate, typically black or white, will be found. This material would be indicative of the discharge of a shotgun as some types of shotshells use it as a buffer filler material.
C. In the case of a non-circular (off-center)/elliptical shot pattern, if the examiner determines it to be appropriate, the angle of the pattern, see Section 6, should be measured.

### *5.7.2 Chemical Residues and their Processing*

A. In the chemical processing of shot patterns, section 5.4 procedures should be used, with the additional considerations outlined below.
    1. At the examiner's discretion, the nitrite and lead residue testing should be performed because it is possible that a shot pattern may contain another bullet hole or other residues.
    2. Although it may be possible to detect vaporous lead and nitrite residues as a result of a shotgun discharge in close range shots, it is normally the pattern of shot which will be the best indicator of the muzzle-to-target distance.
    3. Further, attention should be paid to the possibility of 'pellet wipe' and lead randomly deposited by the impact of wadding materials. Although these types of deposits are not specifically useful in distance determination.

### *5.7.3 Known-Distance Test Patterns*

A. When reproducing shot patterns detected on evidence items it is essential that the suspect firearm and ammunition, or similar, be used to produce test patterns.
B. It is recommended that the known-distance test patterns be fired in butcher paper or similar material affixed to a cardboard target.

C. When reproducing shot patterns, it is appropriate to fire at known-distances that will produce test patterns both smaller and larger than the patterns detected on an evidence item.
    1. Using the known-distance test patterns, a “bracket” is established to include the evidence shot pattern.
        i. Such a “bracket” should be wide enough, typically 1 foot in width to account for differences expected in commercially manufactured ammunition and variations normally expected from shot-to-shot.
D. When reproducing residue patterns, see section 5.6.
E. In the case of non-circular/elliptical patterns, the examiner may attempt to reproduce the pattern by firing at different distances and angles.

## 6 CALCULATIONS

The following equation can be used to determine a very approximate angle of impact for a bullet hole:

$$\text{Angle} = \sin^{-1}(\text{width/length})$$

where width equals the short dimension of the elliptical hole and length equals the long dimension of the elliptical hole.

## 7 LIMITATIONS

The TNV and SoRho tests yield reactions to nitrite and lead residues, respectively, regardless of whether these residues are in fact the result of the discharge of a firearm.

Distance determinations reached because of gunshot residue examinations must be based on residues found to be present, not on the absence of residues.

While shotguns are known to produce consistent shot pattern results under controlled conditions, variables including barrel length, barrel choke and shotshell design can all influence the size and distribution of shot patterns present on the submitted evidence and test-fired exemplars. Accordingly, shot pattern test results are primarily used to exclude particular muzzle-to-target ranges and should only be considered valid for the particular combination of shotgun and type of shotshell used during testing in the Laboratory.

Distance determinations involving a wound and/or injury are outside the scope of this procedure.

## 8 SAFETY

Reagent solutions should be prepared in a manner consistent with current Safety Data Sheet provisions regarding acids and bases. For disposal of the chemicals used for this procedure, refer to section 5 of the Hazardous Waste Disposal.

## 9 REFERENCES


- ANSI/ASB Best Practice Recommendation 068, Safe Handling of Firearms and Ammunition, First Edition, 2020, Sections 4.3 and 4.4.

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## 10 REVISION HISTORY

| Revision | Issued | Changes |
|---|---|---|
| 10 | 03/03/2023 | Drafted with new template requirements. Merged procedures FTD-219-02, FTD-216-04, FTD-220-03. Updates also include addition of the TNV process into the chemical examinations. Added section 6 Calculations. |