# 9.7 Motor Vehicle Identification - Paint Data Query (PDQ)

## 9.7.1 Introduction

An important aspect of forensic paint analysis is the identification of the possible makes, models, and years of manufacture of motor vehicles from paint collected at the scene of a crime or an accident. The color comparison and chemical analysis of the undercoat and topcoat systems requires knowledge of paint formulations and processes, collections of paint standards, and databases of color and composition information.

This procedure describes the general procedure for searching coded FTIR spectra and Munsell color coded primer layers against data contained in the automotive paint database known as Paint Data Query (PDQ).

## 9.7.2 Safety Considerations

### 9.7.2.1

Do not look directly into the FTIR laser.

### 9.7.2.2

If the FTIR Microscope is used, use personal protective equipment to cover eyes and skin while working with liquid nitrogen.

## 9.7.3 Preparations

- Paint Data Query (PDQ) databases (vehicle and spectral)
- Reference collections of manufacturer or repaint color chips
- Reference collection of IR spectra
- Searchable IR spectra platform (e.g. Bio-Rad Know-It-All)
- Munsell color charts

## 9.7.4 Instrumentation

- Stereomicroscope
- Fourier Transform Infrared Spectrometer (FTIR). A microscope accessory is preferred.

**QC and Analytical Results:**

1. Click **User** on the PDQ Main screen, change user to **TEST** in the pop-up window and click the green check button.

2. Open the **Layer System Query** and click **Extract**.

3. Four pre-programmed layer queries will be loaded. Place a check mark beside each layer.

4. Execute the queries by clicking **RUN**, and then **Continue Processing** until all four layer have been searched. Record the number of hits for each query.

5. Check the number of hits against the number of hits posted in the PDQ examination room.

## 9.7.5 Procedure or Analysis

**Installation of the PDQ database**

The current version of the PDQ database must be installed if it is not already available.

1. If present, uninstall the old version of PDQ using **Control Panel > Add/Remove Programs** before installing the new PDQ software.

2. Close all other applications before beginning the installation

3. Insert the new PDQ CD, the WISE setup will start automatically

4. From the PDQ - Paint Data Query screen, click **Next**

5. From the PDQ - Paint Data Query screen, click **Next**

6. Read the licence agreement, if agreed, select **'I accept...**' and click **Next**

7. From the Setup Type screen, select '**Complete**' and click **Next**

Option: Choosing the **Custom** install will allow you to select which libraries to have installed on the computer - (KnowItAll or SearchMaster). **Complete** install automatically install both libraries in the **C:\sadlib folder**

8. From the PDQ Setup screen, click **Next**

9. PDQ will start the installation, this may take a few minutes

10. From the InstallShield Wizard Complete screen, click **Finish**

11. Select 'Yes...' when prompted to restart computer, and the click **Finish**

12. Launch the PDQ program and enter your 4 letter PDQ lab code (UMIL)

13. Perform the Quality Control test (see QC and Analytical Results above under Instrumentation).

## 9.7.5.1

Characterize layer sequence of paint sample using stereomicroscope.

**Paint sample analysis**

1. FTIR spectra are obtained

2. Physical Analysis

    - note the number of layers
    - look at the thickness of the layers
    - look for a galvanized layer (entered in PDQ as SUB GAL)

3. General Guidelines:

**Determining if the system is OEM or repaint based on physical appearance**

| What to look for: | What it can mean |
|---|---|
| Thickness of the Topcoat Paint layer | Unusually thick layer(s) may suggest repaint layer(s). |
| Metallic chips in basecoat | Unusually large metallic flakes in a basecoat may suggest a repaint layer. |
| Thickness of the Undercoat Paint layer | Unusually thick layer(s) may suggest repaint layer(s). |
| Sanding Marks | Paint layer(s) above a layer with sanding marks maybe repaint layer(s) or factory applied repaint layers. |
| Body filler / "Bondo" | Paint layers above a layer of body filler or bondo are most likely repaint layer(s). To confirm a repaint layer, look for thickness, color and air bubbles in the primer layer. |

## 9.7.5.2

Characterize chemistry of individual paint layers by FTIR spectroscopy using flowcharts and/or reference spectra.

**Determining if the system is OEM or repaint by chemistry:**

| What to look for: | What it can mean: |
|---|---|
| 2 different clearcoats /basecoats | If a paint system has 2 different clearcoats/ basecoats, this may suggest repaint layer(s). |
| Melamine | Topcoat paints over metal substrates usually contain melamine with some exceptions. The lack of melamine in a topcoat may suggest a repaint layer, but it could also suggest a layer above a non-metal substrate (plastic,fiberglass etc...), a late 1990s to present paint layer or other possibilities. Some topcoat layers from the late 1990s to present contain trace amounts of melamine and polyurethane. |
| Polyurethane | Polyurethane in a topcoat paint may suggest a repaint, a paint layer above a non-metal substrate, a late 1990s to present paint layer or other possibilities. Some topcoat layers from the late 1990s to present contain trace amounts of melamine and polyurethane. |
| Talc / Clay | Unusually high amounts of talc or clay in an undercoat may suggest a repaint layer. Look for hints such as sanding marks or repainted topcoats to confirm that it is a repaint layer. |
| Calcium Carbonate | Undercoats that are primarily composed of calcium carbonate may be a repaint layer(s) such as a body filler(Bondo). Look for hints such as unusual thickness, colour and air bubbles in this primer layer. |
| E-coat | Most metal frames of a vehicle have an e-coat layer. Metallic substrates which lack the e-coat layer may suggest repaint layer(s). There are a few exceptions, for example, there is a plant in Mexico that does not cover the body with an e-coat. The lack of an e-coat may also suggest that the paint system is very old (before the mid-1980s). |

## 9.7.5.3

If available, characterize color of primer layers according to Munsell color charts.

## 9.7.5.4

Spectral Coding - Enter data from original equipment manufacture (OEM) layers, as determined by IR spectra, into PDQ vehicle database according to software protocol.

<u>Coding Topcoats:</u>

Code only the binders for topcoats (clearcoats and basecoats); do not code pigments and extenders. PDQ does not contain samples for all of the topcoat colors applied on all makes and models, therefore, pigments (and extenders which impart color) should not be coded.

<u>Coding Undercoats:</u>

Code both the binders and pigments/extenders for undercoats. Undercoat layers may have a primer surfacer, an anti-chip layer, an electro-deposition layer (E-coat), as well as other primer layers. The primer surfacer is often the most unique layer in the paint system.

Reference Spectra for Coding Topcoats and Undercoats:

Reference spectra for binders and extenders are contained in the PDQ Spectral Book.

1. Print out the hard copy plots of the topcoat spectra to be coded.

2. Compare the topcoat spectra to each binder reference spectrum and find spectral patterns and key peak locations. Transparent overlays of each binder reference spectra may be used to help code the spectra.

3. All peaks, in the same relative ratios as in the reference spectrum, must be present in the topcoat spectrum in order to code a component unless a peak is hidden by an overlapping peak from another component.

4. Trace amounts of any specific binders should also be noted.

5. If the presence of a particular binder is uncertain, this should also be noted.

Coding Substrates: (metal, plastic and fiberglass)

Most plastic/fiberglass components are not coded and entered in PDQ because some codes have not been created in the PDQ database. It is recommended that codes for plastics not be entered when performing PDQ searches.

| Binder/Resins | | | Pigments/Extenders | | | |
|---|---|---|---|---|---|---|
| Acrylic | ACR | | Carbonate | CAR | | |
| Alkyd | ALK | | Calcium carbonate | CAR | CAC | |
| Isophthalate | ALK | IPH | Aragonite | CAR | CAC | ARA |
| Orthophthalate | OPH | | Calcite | CAR | CAC | CAL |
| Terephthalate | ALK | TER | Chromate | CHR | | |
| Benzoguanamine | BZG | | Potassium zinc chromate | CHR | KZC | |
| Cyano | CYA | | Barium chromate | CHR | BCH | |
| Acrylonitrile | CYA | NIT | Strontium chromate | CHR | SCH | |
| Isocyanate residue | CYA | ICN | Oxide | OXI | | |
| Epoxy | EPY | | Iron oxide | OXI | FEO | |
| Melamine | MEL | | Red | OXI | FEO | RED |
| Nitrocellulose | NCL | | Yellow | OXI | FEO | YEL |
| Polybutadiene | PBD | | Lead oxide | OXI | PBO | |
| Polyurethane | PUR | | Silicon dioxide | OXI | SIO | |
| Styrene | STY | | Cristobalite | OXI | SIO | CRI |
| Urea | REA | | Opal | OXI | SIO | OPA |
| | | | Quartz | OXI | SIO | QUA |
| | | | Titanium dioxide | OXI | TIO | |
| | | | Rutile | OXI | TIO | RUT |
| | | | Anatase | OXI | TIO | ANA |
| | | | Zinc oxide | OXI | ZNO | |
| | | | Zinc phosphate | PHO | ZNP | |
| | | | Silicate | SIL | | |
| | | | Magnesium silicate (talc) | SIL | MGS | TAL |
| | | | Aluminum silicate (clay) | SIL | ALS | KAO |
| | | | Barium sulphate | SUL | BAS | |

**Basic components:** Examine the spectrum for the following basic components when coding a layer of OEM automotive paint, but not to the exclusion of any other chemical components that may also be present in the paint system.

| LAYER | COMPONENTS |
|---|---|
| Clearcoats | ACR MEL STY PUR plus other binders/resins |
| Basecoats | ACR MEL STY ALK IPH PUR plus other binders/resins |
| Primer surfacer | ACR MEL EPY (trace) OXI TIO RUT SILs BAS PUR plus other binders/resins and pigments/extenders |
| E-coat | EPY OXI TIO RUT SIL ALS KAO PUR PHO ZNP SUL BAS (newer) plus other binders/resins and pigments/extenders |

## 9.7.5.5

Compare spectra of possible source vehicles using PDQ spectral database.

**Performing PDQ Searches**

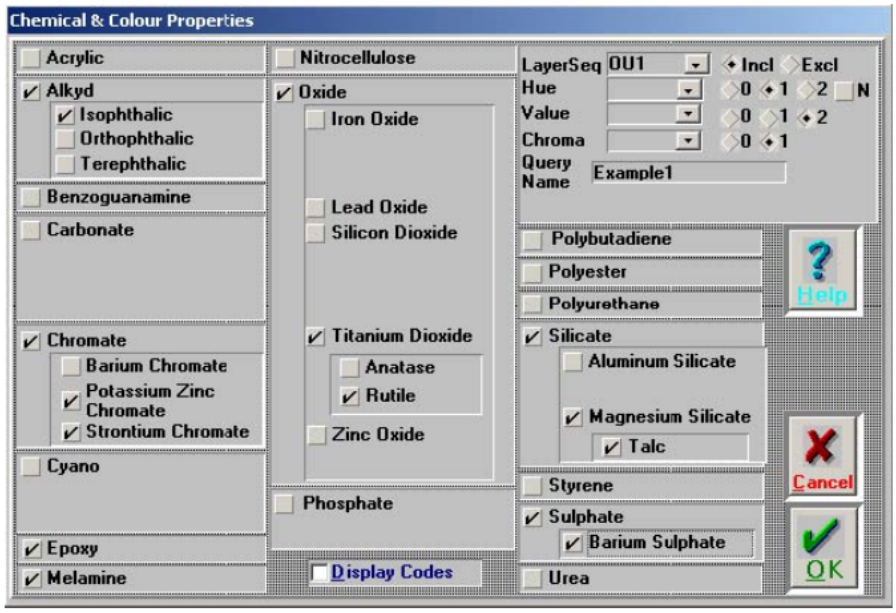
Layer System Query (LSQ):

Perform a query of the chemical components from each paint layer. This is a multi-line query, where the results of one query line are used as the source for the next query line.

The first search should always be general, entering minimal data to ensure no paint layers are excluded due to subtle differences in the chemical components and subsequent coding.

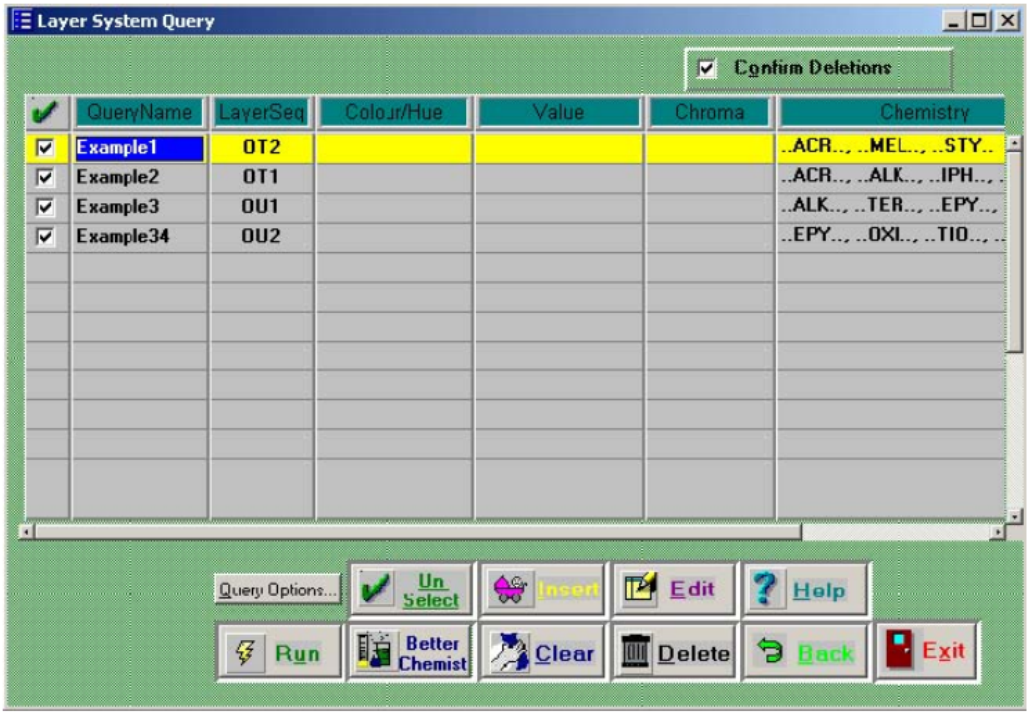
1. From the **PDQ Main Screen**, select **Layer System Query** and click on **Extract**.
2. From the **Layer System Query** screen, click on **Insert**.

3. From the **Chemical and Color Properties** screen enter the layer sequence (e.g. OT2, or OT1, etc) and enter the chemical components (e.g. EPY and/or KAO, etc).




4. Click on **OK** to return to the **Layer System Query** screen
5. To enter the chemical components of other layers, repeat steps 2 to 4.

6. From the **Layer System Query** screen, ensure that the layers to be queried are selected with a check mark and click on **Run**

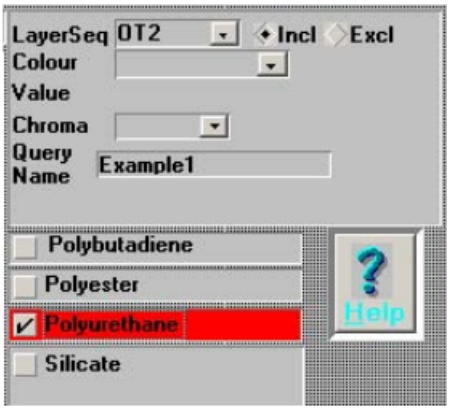



Other LSQ search strategies:

1. Avoid entering the colour/hue or chroma on initial searches because this could eliminate valuable hits.

2. The construction of the initial search queries should always be generic. Do not code trace components or components whose identity is uncertain. Subsequent searches may be refined by adding more specific components.

3. To exclude a component from a search query, press the **Shift** key and select the component. The selected component will turn red.

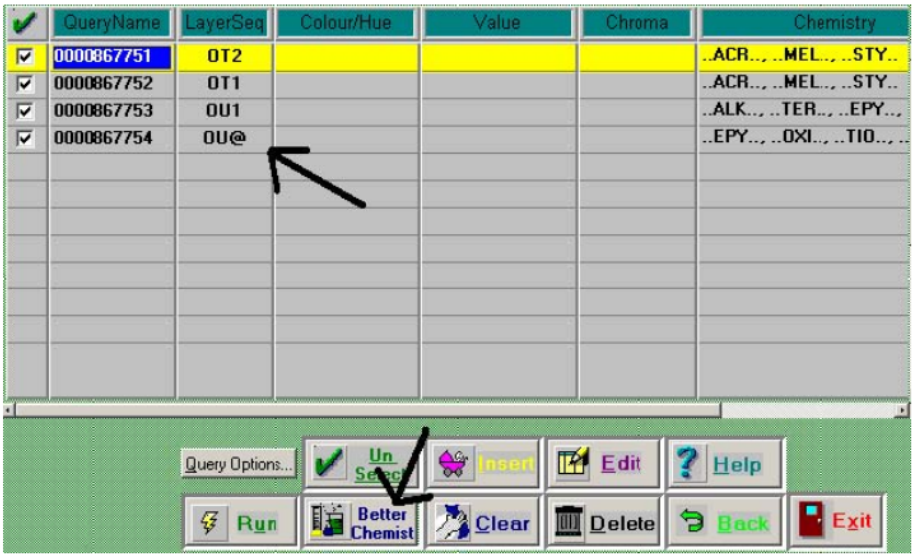



4. Better Chemist

A. Click the **Better Chemist** button on the **Layer System Query** page.

B. The program enters **Edit** mode.

C. Edit the entered queries. For example, wildcards (@) may be inserted to expand the search criteria (changing OU1 to OU@ will result in a search for all Original Undercoat layers with the entered chemical components).




<u>Editing Layer System Query (LSQ) Searches:</u>

1. In the **Query Results**! screen, click **Abort Query**.

2. In the **Layer System Query** screen, select the **Query Name** to edit.

3. In the **Layer System Query** screen, click **Edit**

4. Edit the query by either including or excluding chemical components. To exclude a component from a search query, press the Shift key and select the component. The selected component will turn red.

5. Click **OK** to return to the **Layer System Query** screen.

6. To edit another layer, repeat steps 2 through 5.

7. Select all layers to be queried with a check mark and click **Run**.

8. Click **Continue Processing** until all selected layers have been searched.

9. Click **Print Query** to print a hard copy of the search query parameters.

10. Click **View Results**! to see the results (see Viewing Results).

Fill-in-the-Blank (FITB) Searches:

A Fill-in-the-Blank query searches the sources of samples held in the database. For example, specific plants, manufactures, and year ranges may be searched:

1. On the **PDQ Main Screen**, select **Fill-in-the-Blank** and click **Extract**.

2. On the **Fill-in-the-Blank Query Table** screen, click **Add**.

3. On the **Query Record Edit** screen, select the option(s) to query using the look-ups tables.

4. Click the **Execute** button.

5. Click **Print Query** to print a hard copy of the search query parameters.

6. Click **View Results**! to see the results (see Viewing Results).

Other FITB search strategies:

1. It is a good practice to use the look-up tables (click the binoculars icon) to ensure accurate search results.

2. A FITB search can be used to determine, or narrow down, a year range.

3. A FITB search can be used to widen a search, for example, to view all vehicles in a specific search, such as, viewing all Fords between 1995 and 1999.

4. Use the PDQ Code Book to assist with defining specific codes.

Integrating LSQ and FITB Searches:

Both FITB and LSQ searches can be integrated together, for example, a FITB search could be used to refine the results from a LSQ search or vice versa. For example, when a specific manufacturer is suspected or known, it is possible to extract that manufacturer using the FITB search, and then to use those results in a search of the layers entered in the LSQ search. The integrated search can be used to narrow down a year range when the manufacturer or plant is already known or strongly suspected.

1. Execute a FITB search.

2. Click the **Do Layer System** button on the **Query Results**! screen.

3. Follow the procedures for a LSQ search as outlined in this SOP.

Alternatively,

1. Execute a LSQ search

2. Click the **Do FITB** button on the **Query Results**! screen.

3. Follow the procedures for a FITB search as outlined in this SOP.

**Viewing Results**

1. The default setting for viewing results is **Table View**.

2. Click **View Results** from either of the search types (LSQ or FITB) to bring up the **Table View** screen.

3. The search results are shown in the yellow tabs, while the whole database is shown in the red tabs. The information displayed in the tabs is set in the **User Preferences** part of the software. Any information not selected in **User Preferences** will be 'greyed-out'.

4. To extract information that is 'greyed-out', click **Result File Options** on the **Table View** screen, or edit the **User Preferences** by returning the main screen and clicking the **Tools** button and then the **User Preferences** tab.

Layers Results

1. Select the yellow **Layer Results** tab to view the chemistry of each layer.

2. The data display may be modified as follows:

A) Column Position: click any of the chemistry lines to highlight it in blue. Then click the left arrow **Column Position** 4 times to position the **Chemistry** column beside the **LayerSeq** column.

B) Display Order: select **LayerSeq** from the **Display Order** drop down list. NOTE: This view setup is now sorted to allow the user to see all of the layer sequences and chemistries side by side so that components can be noted and used for narrowing down the hit list.

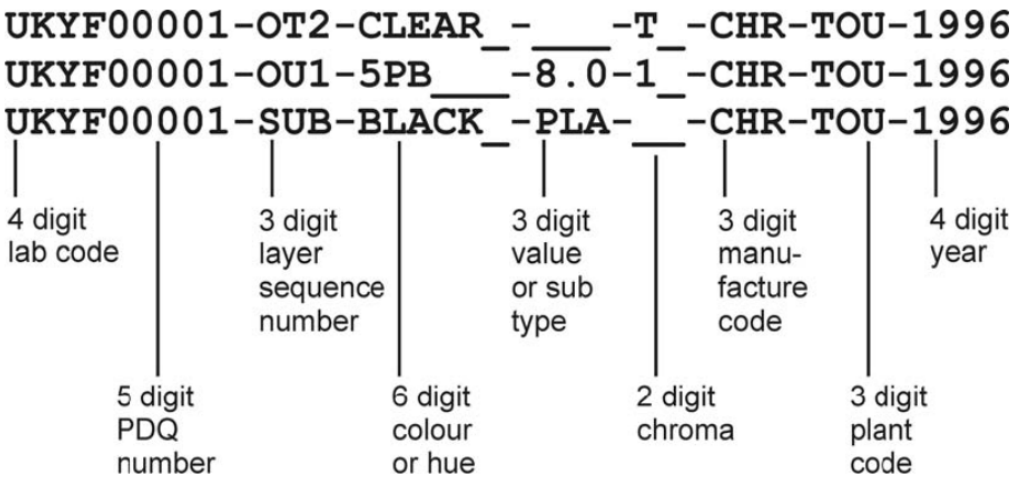
3. Filter through the Chemistry column and remove hits that have components not present in the unknown.

4. When finished, click the green **Back Arrow** (see also Editing Layer System Query(LSQ) Searches)

**Spectral Library Searches and Extractions**

Currently, there is no link between PDQ and the digital spectral libraries. Each spectrum can only be opened manually using spectral search software, such as Know-it-All or Bio-Rad SearchMaster. Different search algorithms (e.g. 1st derivative, Euclidean distance, etc.) may be used to generate the best possible hit list. It is recommended that a hit list size of 50 or more be used.

Any part of the spectrum name can be searched by performing a Name Search. The name format for each spectrum is shown below:




<u>Name Search - Extracting a Specific Layer or Layer System from the PDQ Libraries</u>

The following paint system will be used as an example: UAZP00080 - 1999 Ford Mustang built at the Dearborn plant. The following steps describe how to open one or more spectra from the UAZP00080 paint system.

A. Extract one specific layer:

1. Select to perform a Name search.

2. Enter the known information (e.g. UAZP00080 and OU1).3. Execute the search.

B. Extract all spectra from a layer system:

1. Select to perform a Name search.

2. Enter the PDQ number (e.g. UAZP00080).

3. Execute the search.

C. Compare an unknown spectrum to a specific spectrum from the PDQ libraries:

1. Open the unknown spectrum.

2. Select to perform a Name search.

3. Enter the known information (e.g. UAZP00080 and OU1).

4. Execute the search.

D. Spectral Search - Extract a spectrum with a high Hit Quality IndexExtracting a similar spectrum:

1. Open the unknown spectrum.

2. Select to perform a Spectral Search.

3. Execute the search.

E. Combination: Extract a similar spectrum and specifying a name

1. Open the unknown spectra.

2. Select to perform a Combination search (ensure to specify Spectral search and Name search).

3. Enter the specific name component(s).

4. Execute the Combination search.

**Narrow the Year Range**

The PDQ Spectral Libraries can be used to narrow down a year range. For example, if a manufacturer and plant is suspected, a combined Name search and Spectral search could be performed to narrow down the year range using the search software and the PDQ libraries.

### 9.7.5.6

Compare color of basecoat with color chips of possible source vehicles.

**Search the Refinish Books (Dupont, PPG, etc...)**

One of the final steps in a paint search is to confirm the findings by comparing the unknown paint chip to the color standards contained in the refinish books. This step verifies that the color of the unknown paint chip was actually used by the auto manufacturer(s) in the year(s) suggested by the results obtained form the database. Searching the refinish books may also be used to narrow down a year range. Note: it is recommended to add a year to each end of a year range because colors may be phased in and out by a manufacturer.

### 9.7.5.7

Prepare hard copies of searched parameters and results of useful PDQ searches

Note: Section 3 of the PDQ Content Manual

Section 3 of the PDQ Content Manual contains information from North American and Mexican assembly plants. This section of the manual lists all the lines of vehicles built at each assembly plant each year.

### 9.7.5.8

Prepare hard copies of spectral comparisons.

### 9.7.5.9

Documentation must meet standards and controls requirements.

## 9.7.6 PDQ Abbreviations

The PDQ software “Lookup Tables” contain the definitions of abbreviations used in performing and interpreting queries. The abbreviations in those tables are approved for utilization in examination documentation.

## 9.7.7 References

• PDQ Content Manual

• PDQ Spectral Book

• PDQ Code Book

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