

COMMERCIAL VEHICLE BRAKE SENSOR PERFORMANCE DATABASE AND ANALYSIS TOOL

User's Guide

Prepared for

**United States Department of Transportation
Federal Motor Carrier Safety Administration**

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PROGRAM INTRODUCTION

Under Section 5117 of the Transportation Equity Act for the 21st Century of 1998 (TEA-21), Congress required the U.S. Department of Transportation to “conduct research on the deployment of a system of advanced sensors and signal processors in trucks and tractor trailers to determine axle and wheel alignment, monitor collision alarm, check tire pressure and tire balance conditions, measure and detect load distribution in the vehicle, and adjust automatic braking systems”. The research program responding to this directive is called the “Commercial Vehicle Safety Technology Diagnostics and Performance Enhancement Program”, (i.e., “CV Sensor Study”).

Task Order #3 “On-board Sensors for Determining Brake System Performance” was completed as a task under the CV Sensor Study Program.

The overall objective of Task Order #3 research program was to document the performance and operational characteristics of leading-edge technological approaches to monitoring commercial vehicle braking systems. This study focused on examining the ability of various sensors to detect abnormalities, defects, and/or miss-adjustments of the brake system. The output of this study was a technical examination of the accuracy, responsiveness, resolution, and reliability of the various systems. This knowledge should prove useful to fleet operators in evaluating the capabilities and limitations of alternative brake sensing approaches, and in determining specifications for future truck purchases. The information should also be useful to brakes system suppliers and commercial vehicle manufacturers that are developing new brake monitoring systems. To this extent, the objectives for the study include providing fundamental research results to industry stakeholders concerning various means of monitoring braking systems.

Specific objectives and questions to be addressed by the study include the following:

- Instrumented anchor pins for S -cam drum brakes – Does the output provide an accurate representation of braking forces? Is it necessary to instrument both upper and lower anchor pins? How responsive is the output? How could the sensors be used to detect defects? Is a “simplified” design possible?
- Wheel-speed sensing – Can ABS wheel speed sensors be used to determine wheel slip and its relationship to brake force be used to detect brake system defects?
- Air chamber stroke sensing systems are already available in the marketplace. How accurate and reliable are such systems? What defects can they detect? What malfunctions might they miss or not detect? Is it important to monitor brake stroke continuously, or is measurement of over/under stroke sufficient?
- Deceleration measurements – Comparing deceleration with air brake pressure input to determine total brake force can be used to detect brake defects.

However, several important design issues remain unanswered. How accurate do the accelerometer and pressure transducers need to be? What is the allowable tolerance on input of the vehicle weight to produce reliable results? How does the system respond to normal brake wear? Does the system produce excessive “false positives” such that warnings might be ignored? Also, the operational issues associated with having to make a hard “test” brake application at over 40 mph in order to catch adjustment problems needs to be studied, although this is also an issue with other methods that measure brake force.

- On-board brake temperature measurement – As noted, relatively low-cost thermocouples could readily be affixed to brake system components. But, could the output be reliably used to detect defects? How responsive are such sensors?

The various systems were installed (simultaneously) on a conventional tractor-trailer combination vehicle and tested under controlled braking maneuvers on a test track. (Radlinski and Associates, Inc., completed all work at the Transportation Research Center [TRC] in Columbus, Ohio). The output of the various brake sensor systems could then be compared on the same vehicle under identical testing conditions. This approach facilitated objective, accurate comparison of the sensors, and eliminates problems associated with test procedure repeatability when comparing different systems.

A test matrix was developed and executed that included a variety of braking maneuvers, including low to high deceleration rates executed on dry and wet pavement, on both level and graded surfaces, and in loaded (GVW) and unloaded (Lightly Loaded Vehicle Weight, LLVW) test conditions. Baseline performance and sensor outputs were first established with all wheel/brake assemblies on the vehicle optimally adjusted and with no defects. Braking performance of the vehicle was verified using a roller dynamometer Performance Based Brake Tester (PBBT). This methodology allowed for comparison of the brake force measurements from the various sensors with an accepted reference standard. The test matrix included introducing pre-planned faults or defects on selected brake assemblies and repeating various braking maneuvers. The outputs from the sensor packages were then examined to determine their ability to detect brake defects under a variety of braking conditions. Defects examined included various levels of out-of-adjustment brakes, disconnected brakes, and oil-soaked brakes.

Data from the sensors packages were recorded using an onboard PC-based data-logging system capable of recording digital, analog, and discrete sensor outputs. The system was also capable of simultaneously monitoring data (such as wheel speed output) on the J1939 data bus.

The data generated from the brake test program was imported into a Microsoft Access database specifically developed for this project. A graphing applet (Tee Chart Pro, Steema Software SL, Catalonia, Spain) capable of presenting multiple sensor outputs and scales on a single chart was embedded into the database. This chart-developing capability was instrumental in sifting through and identifying trends in the data.

This database and chart-developing capability, was included with the final report as this **Commercial Vehicle Brake Sensor Performance Database and Analysis Tool**. It includes all of the data from the Brake Sensor program, along with a graphical user interface (GUI) which includes the graphing tool developed.

As this tool was developed as a means to analyze the data from the individual braking stops (not the simulated city and simulated mountain cycles) and develop the final report, it was not intended to be a “full-featured” stand-alone software application, and therefore has not gone through the rigorous testing and evaluation process of a production application.

CHAPTER 1: INSTALLING AND OPENING THE DATABASE TOOL

This section provides instructions on how to install and open the Commercial Vehicle Brake Sensor Performance Database and Analysis Tool on your machine.

SYSTEM REQUIREMENTS

The suggested minimum requirements to run the Database and Analysis Tool using Access are as follows.

- An IBM-Compatible PC
- 350 Megabytes of free hard drive disk space
- Microsoft Windows 2000 operating system
- MS Access 2000 software

MS Access Requirement: The tool was developed within Microsoft's MS Access 2000 software package. As such, it is crucial that this software package be installed on the user's computer prior to attempting to open and run the tool. Otherwise, the tool will not function.

Windows 2000/XP Requirement: The embedding graphing applet, TeeChart, was designed as an ActiveX applet for Visual Basic. As such, it is crucial that the user's computer be running Windows 2000 or later operating system prior to attempting to install and run the tool. While, this tool might function under Windows 98/ME, it has not been tested with these operating systems.

LOADING AND OPENING THE MODEL

Loading and Opening the Tool: To load the tool onto your computer:

If you received a CDROM version:

1. Insert the CDROM into your CDROM drive.
2. Double-click on the My Computer icon on your desktop
3. Double-click on your CDROM drive (e.g., D)
4. Double-click on the file "**BrakeSensorInstall.msi**"
5. Follow the prompts in the installer application to install the tool on your computer
6. Once the installation is complete you can double-click on the shortcut called "**Brake Sensor Database**" on your desktop or find it under Programs in your Start Menu.

If you downloaded the tool from the Internet:

7. Double-click on the file "**BrakeSensorInstall.msi**"
8. Follow the prompts in the installer application to install the tool on your computer
9. Once the installation is complete you can double-click on the shortcut called "**Brake Sensor Database**" on your desktop or find it under Programs in your Start Menu.

CHAPTER 2: USING THE PERFORMANCE DATABASE AND ANALYSIS TOOL

OVERVIEW OF TOOL

Please see the project report Chapter 4 for a complete overview of the test plan. The chapter explains the test matrix, brake deficiency codes and locations, and the list of sensors with acronyms. The information in Chapter 4 will help you interpret the data and enhance the understanding of this analysis tool.

After launching the application, the first window that appears provides some background information about the Brake Sensor Study and the Analysis Tool. Press the **Close** button to exit.

Next, you'll see the main screen of the database analysis tool. There are four tabs at the top of the screen that allow you to switch between different applications, or "data views" within the tool. These data views include:

1. Compare Channels
2. Compare Runs
3. Channel vs. Channel
4. Individual Runs

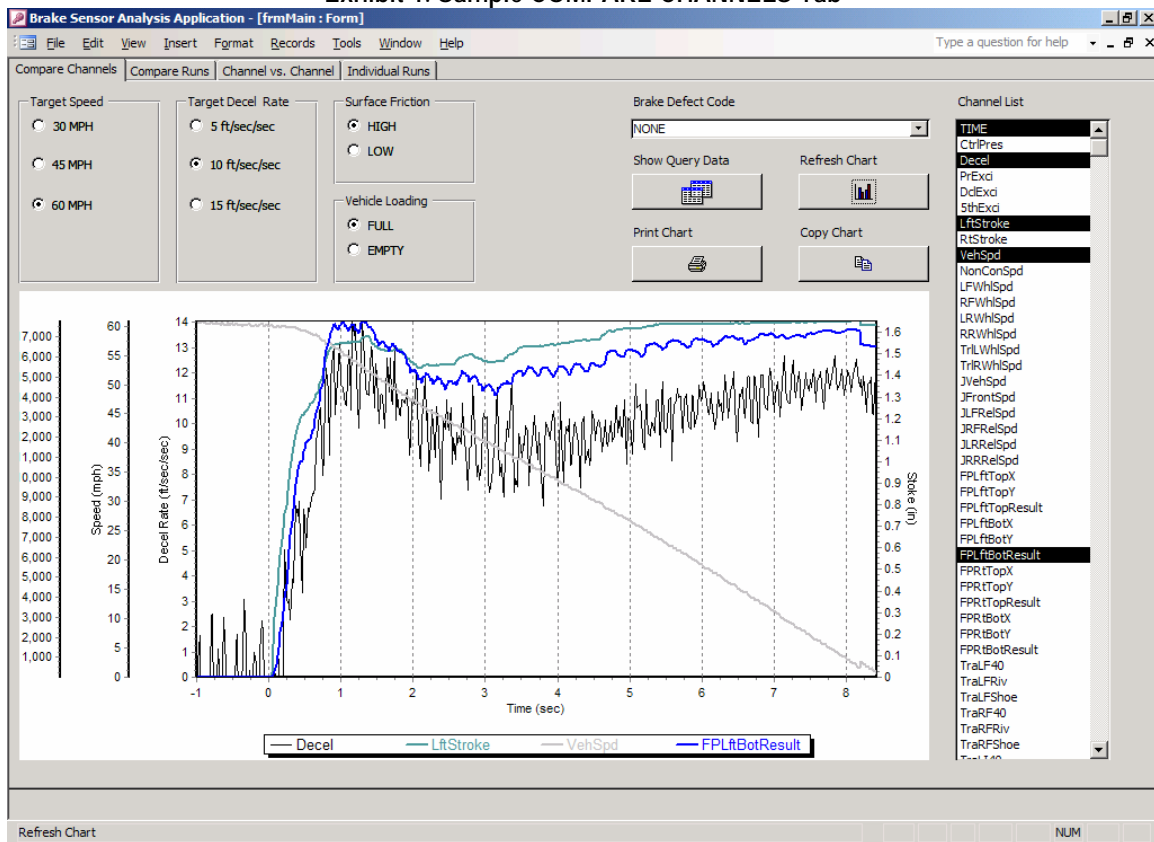
Clicking on the tabs switches between the different data views..

COMPARE CHANNELS TAB

With this view, the data from any one, or all, of the 55 individual sensors can be displayed simultaneously for any specified set of test runs which meet a given set of conditions, including: initial speed, deceleration rate, surface friction, loading, and defect code criteria. For example, Exhibit 1 shows a screen capture for the "Compare Channel" data view. This menu screen permits the user to simultaneously graph multiple channels from test runs that meet a specified set of test conditions. After the user selects specific test conditions, the database retrieves the individual test runs matching those conditions and averages them together in order to develop a "typical" test run for the conditions specified by the user.

In Exhibit 1, the user selected the following conditions: a target speed of 60 mph; a deceleration rate of 10 ft/sec/sec; a high surface friction (dry pavement); a fully loaded vehicle, and, no brake defects. The user also selected four channels: (deceleration rate, brake stroke; vehicle speed; and the resultant force of the driver-side bottom anchor pin) to all be displayed versus time. As shown in Exhibit 1, 9 seconds elapsed to bring the truck to a stop from 60 mph. The anchor pin force recorded during this braking event exceeded 16,000 pounds and the stroke peaked at 1.5 inches.

Exhibit 1. Sample COMPARE CHANNELS Tab



To query the database:

1. Select a target speed for the test run by clicking on an option circle in the box marked **Target Speed**. Options are 30, 45, or 60 mph.
2. Select a target deceleration rate for the test run by clicking on an option circle in the box marked **Target Decel Rate**. Options are 5, 10, or 15 ft/sec/sec.
3. Select the surface friction by clicking on an option circle in the box marked **Surface Friction**. Options are HIGH or LOW.
4. Select the vehicle loading by clicking on an option button in the box marked **Vehicle Loading**. Options are FULL (GVWR) or EMPTY (CURB WEIGHT).
5. Select the brake defect code by clicking on the drop-down combo box labeled **Brake Defect Code** and selecting an entry from the list. Choose NONE for no brake defects.
6. Select the channels you would like to view by click on the list on the **Channel List** box. You must always select TIME.

Warning!

You must always select **TIME** as a channel in the channel list, otherwise no data will be displayed.

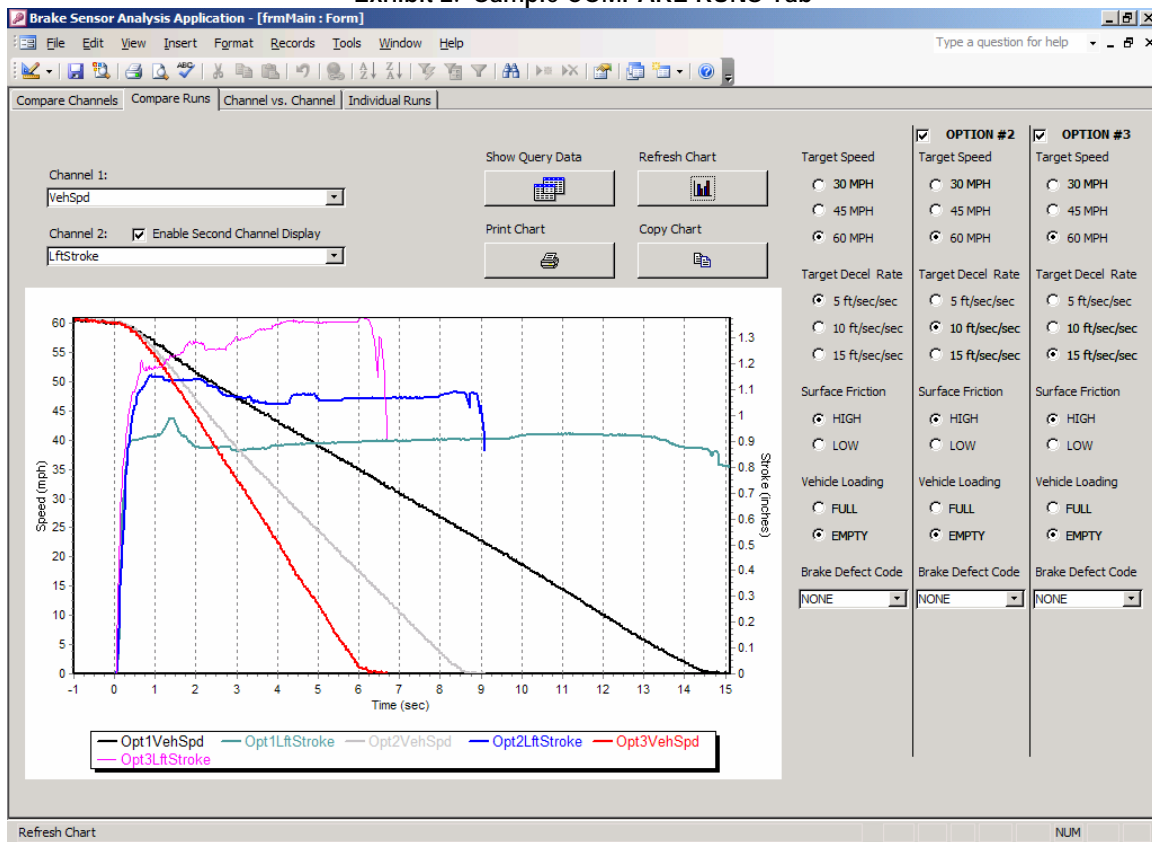
7. To view the raw results, click on **Show Query Data** button. This opens a new database window with the results of the query based upon your previous selections. Click the small X in the upper right corner to close this new window.
8. To view a graph of the data, click the **Refresh Chart** button. The graph should then be updated.
9. To print the graph, click the **Print Chart** button. This will open another window, allowing for you to format the printer output and select printers.
10. To copy the chart to your clipboard, click the **Copy Chart** button. You can select the picture format and click **Copy** to place a copy of the picture in the clipboard (you can then paste it in another application). Also, if you click the **Save** button you can save it to a file. If you click **Send**, and you have a default e-mail application setup, you can send the chart picture as an attachment to an e-mail.

COMPARE RUNS TAB

The Compare Runs tab permits the user to display up to three test runs and two data channels simultaneously versus time. It differs from the compare channels tab by allowing the user to display data between different runs or braking maneuvers.

A sample output of the "Compare Runs" data view is shown in Exhibit 2. The user wished to graphically view vehicle speed and stroke sensor output for three different brake maneuvers versus time. All three brake maneuvers occur at a target speed of 60mph, on dry pavement, and with an empty load, but with different target deceleration rates (5, 10, 15 ft/sec/sec). As one would anticipate, the higher the deceleration rate, the higher the brake chamber stroke, and the faster the truck came to a stop. Also note that the graph was generated with no brake deficiencies as seen in the bottom right-hand side of the screen capture. As shown, the elapsed time required to stop the truck varied between approximately 6 and 14 seconds; brake stroke travel varied between 0.9 and 1.4 inches.

Exhibit 2. Sample COMPARE RUNS Tab



To query the database:

1. Select the first channel you would like display using the drop-down combo box labeled **Channel 1**.
2. If you would like to display a second channel simultaneously, select the check box labeled **Enable Second Channel Display**. Then select the second channel you would like to display from the now active drop-down combo box labeled **Channel 2**.

Warning!

You do not need to select TIME as a channel in this tab.

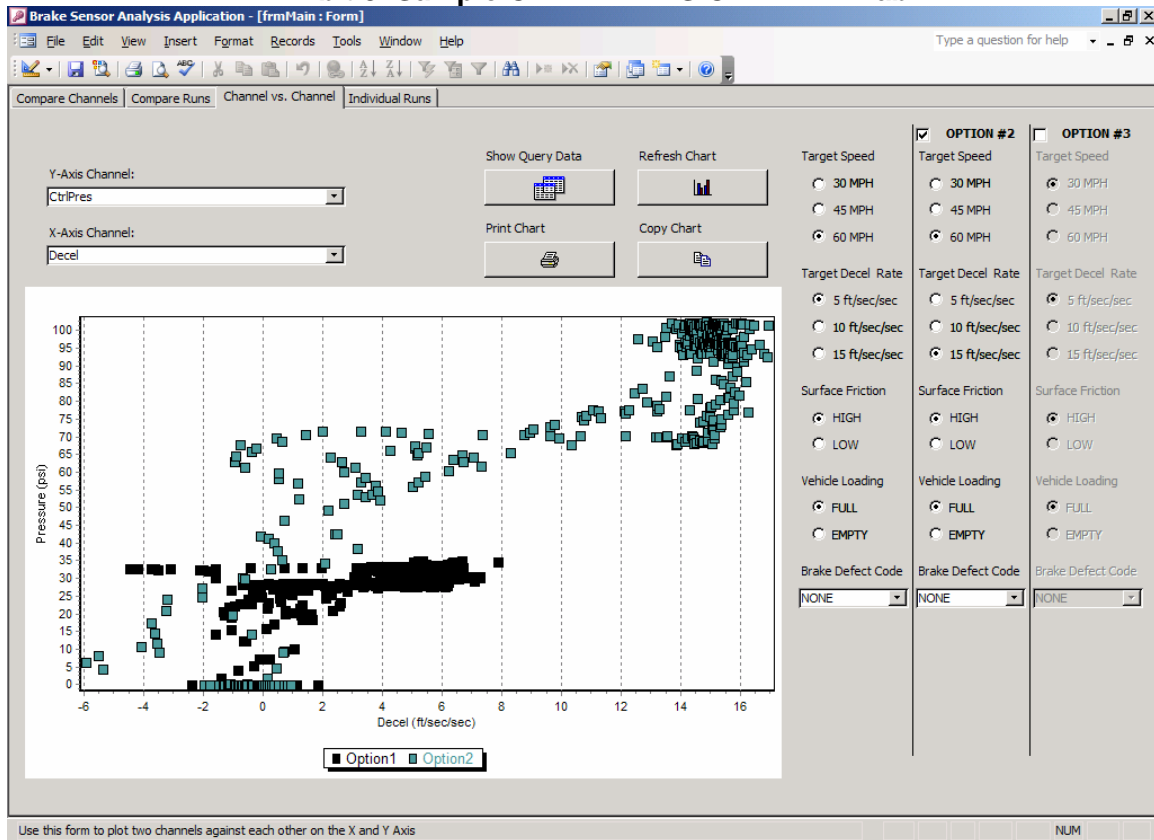
3. Select a target speed for the first test run by clicking on an option circle in the box marked **Target Speed**. Options are 30, 45, or 60 mph.
4. Select a target deceleration rate for the test run by clicking on an option circle in the box marked **Target Decel Rate**. Options are 5, 10, or 15 ft/sec/sec.
5. Select the surface friction by clicking on an option circle in the box marked **Surface Friction**. Options are HIGH or LOW.
6. Select the vehicle loading by clicking on an option button in the box marked **Vehicle Loading**. Options are FULL (GVWR) or EMPTY (CURB WEIGHT).

7. Select the brake defect code by clicking on the drop-down combo box labeled **Brake Defect Code** and selecting an entry from the list. Choose NONE for no brake defects.
8. To enable a second test run to be viewed, check the box labeled **Option #2**. Then follow steps 3 – 6 for the now active Option #2 selections.
9. To enable a third test run to be viewed, check the box labeled **Option #3**. Then follow steps 3 – 6 for the now active Option #3 selections.
10. To view the raw results, click on **Show Query Data** button. This opens a new database window with the results of the query based upon your previous selections. Click the small X in the upper right corner to close this new window.
11. To view a graph the data, click the **Refresh Chart** button. The graph should then be updated.
12. To print the graph, click the **Print Chart** button. This will open another window, allowing for you to format the printer output and select printers.
13. To copy the chart to your clipboard, click the **Copy Chart** button. You can select the picture format and click **Copy** to place a copy of the picture in the clipboard (you can then paste it in another application). Also, if you click the **Save** button you can save it to a file. If you click **Send**, and you have a default e-mail application setup, you can send the chart picture as an attachment to an e-mail.

CHANNEL VS CHANNEL TAB

Exhibit 3 shows a screen capture of the CHANNEL VS CHANNEL data view. This data view is similar to the COMPARE RUNS screen, but there is one significant difference—it provides the user with the capability to plot one channel versus another channel (instead of versus time as in the two previous menu options). As shown in Exhibit 3, the user chose to plot pneumatic control pressure versus deceleration for two different brake maneuvers--the first at a deceleration rate of 5 ft/sec/sec and the second at a deceleration rate of 15 ft/sec/sec. Intuitively, the brake maneuver conducted at the higher deceleration rate would result higher control pressures. The plot of control pressure versus deceleration rate in Exhibit 3 confirms this observation.

Exhibit 3. Sample CHANNEL VS CHANNEL Tab



To query the database:

14. Select the first channel you would like display on the Y-axis using the drop-down combo box labeled **Y-Axis Channel**.
15. Select the first channel you would like display on the X-axis using the drop-down combo box labeled **X-Axis Channel**.

Warning!

You do not need to select TIME as a channel in this tab.

16. Select a target speed for the first test run by clicking on an option circle in the box marked **Target Speed**, Options are 30, 45, or 60 mph.
17. Select a target deceleration rate for the test run by clicking on an option circle in the box marked **Target Decel Rate**. Options are 5, 10, or 15 ft/sec/sec.
18. Select the surface friction by clicking on an option circle in the box marked **Surface Friction**. Options are HIGH or LOW.
19. Select the vehicle loading by clicking on an option button in the box marked **Vehicle Loading**. Options are FULL (GVWR) or EMPTY (CURB WEIGHT).
20. Select the brake defect code by clicking on the drop-down combo box labeled **Brake Defect Code** and selecting an entry from the list. Choose NONE for no brake defects.

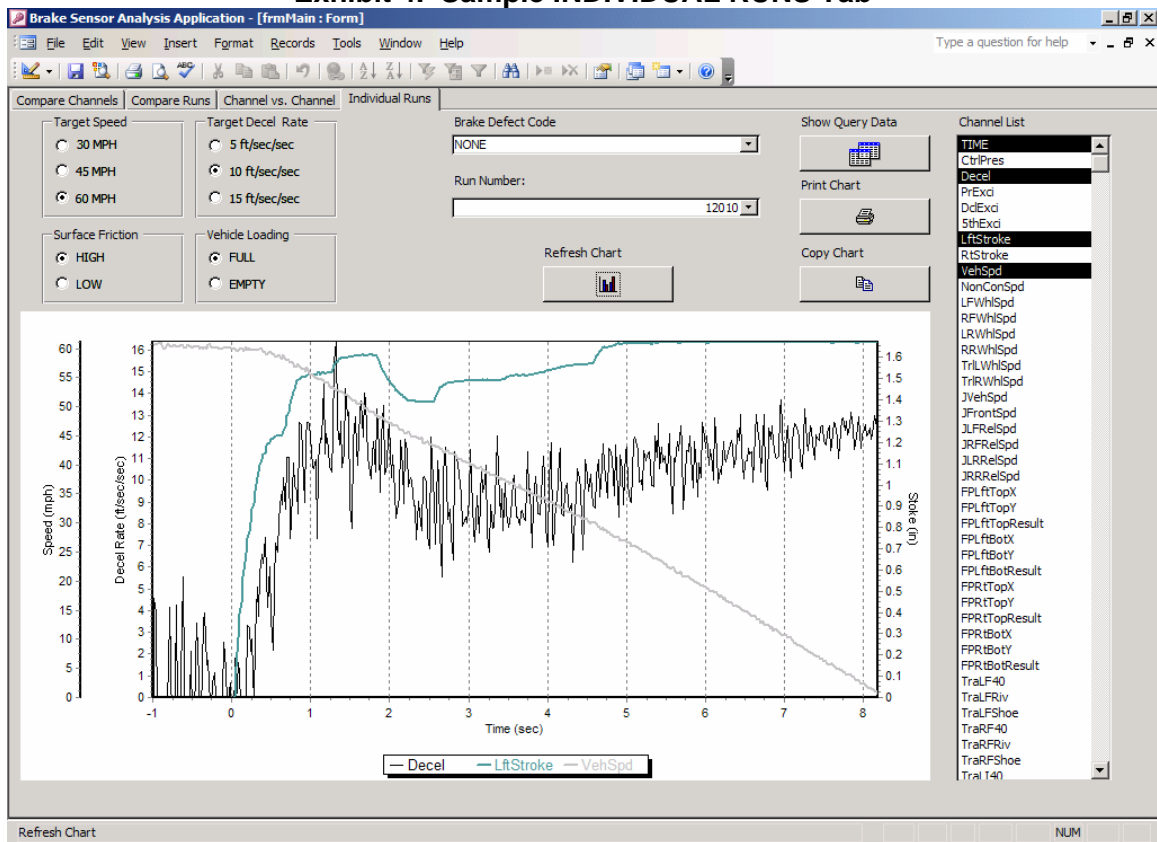
21. To enable a second test run to be viewed, check the box labeled **Option #2**. Then follow steps 3 – 6 for the now active Option #2 selections.
22. To enable a third test run to be viewed, check the box labeled **Option #3**. Then follow steps 3 – 6 for the now active Option #3 selections.
23. To view the raw results, click on **Show Query Data** button. This opens a new database window with the results of the query based upon your previous selections. Click the small X in the upper right corner to close this new window.
24. To view a graph of the data, click the **Refresh Chart** button. The graph should then be updated.
25. To print the graph, click the **Print Chart** button. This will open another window, allowing for you to format the printer output and select printers.
26. To copy the chart to your clipboard, click the **Copy Chart** button. You can select the picture format and click **Copy** to place a copy of the picture in the clipboard (you can then paste it in another application). Also, if you click the **Save** button you can save it to a file. If you click **Send**, and you have a default e-mail application setup, you can send the chart picture as an attachment to an e-mail.

INDIVIDUAL RUNS TAB

The INDIVIDUAL RUNS data view is very similar to the COMPARE RUNS tab, except that in this view, you can look at specific runs by run number (as opposed to the COMPARE RUNS data view which shows the average of a series of runs with the same criteria). In this tab, the data from any one, or all, of the 55 individual sensors can be displayed simultaneously for a single test run which meet a specified set of conditions, including: initial speed, deceleration rate, surface friction, loading, and defect code criteria.

Exhibit 4 shows an example of the INDIVIDUAL RUNS data view for run number 12010. Run number 12010 corresponds to a brake maneuver initiated from a target speed of 60 mph at a deceleration rate of 10 ft/sec/sec, on dry pavement, with a full load, and with no brake defects. It is important to note that knowing the specifics of an individual test run is not necessary to operate this menu screen since the user selects from a list of parameters (i.e. target speed, decel. rate, etc.), the database then automatically queries the data for run numbers meeting those conditions. The matching run numbers are then displayed in a drop-down display box under the heading "Run Number". In Exhibit 4, vehicle speed, deceleration rate, and stroke are plotted versus time. As shown, the deceleration rate swings as the driver modulates the treadle valve attempting to close in on a 10 ft/sec/sec deceleration rate. During this event, the stroke reaches a maximum of 1.6 inches.

Exhibit 4. Sample INDIVIDUAL RUNS Tab



To query the database:

11. Select a target speed for the test run by clicking on an option circle in the box marked **Target Speed**. Options are 30, 45, or 60 mph.
12. Select a target deceleration rate for the test run by clicking on an option circle in the box marked **Target Decel Rate**. Options are 5, 10, or 15 ft/sec/sec.
13. Select the surface friction by clicking on an option circle in the box marked **Surface Friction**. Options are HIGH or LOW.
14. Select the vehicle loading by clicking on an option button in the box marked **Vehicle Loading**. Options are FULL (GVWR) or EMPTY (CURB WEIGHT).
15. Select the brake defect code by clicking on the drop-down combo box labeled **Brake Defect Code** and selecting an entry from the list. Choose NONE for no brake defects.
16. Then, select the run number by clicking on the drop-down combo box labeled **Run Number** and selecting an entry from the list. NOTE: if there are no entries listed, then no test runs were performed for that combination of Target Speed, Target Deceleration Rate, Surface Friction, Vehicle Loading, and Brake Defect Codes.
17. Select the channels you would like to view by click on the list on the **Channel List** box. You must always select TIME.

Warning!

You must always select **TIME** as a channel in the channel list, otherwise no data will be displayed.

18. To view the raw results, click on **Show Query Data** button. This opens a new database window with the results of the query based upon your previous selections. Click the small X in the upper right corner to close this new window.
19. To view a graph the data, click the **Refresh Chart** button. The graph should then be updated.
20. To print the graph, click the **Print Chart** button. This will open another window, allowing for you to format the printer output and select printers.
21. To copy the chart to your clipboard, click the **Copy Chart** button. You can select the picture format and click **Copy** to place a copy of the picture in the clipboard (you can then paste it in another application). Also, if you click the **Save** button you can save it to a file. If you click **Send**, and you have a default e-mail application setup, you can send the chart picture as an attachment to an e-mail.