TS 1033190 - Vibration Analysis Training

Vibration Analysis Training - Updated 8/2018

Click on the PowerPoint file in the attachments section of this document to view the training file.

Note: This updated Vibration Analysis includes Smart Phone and other mobile devices.

DAIMLER

Vibration Analysis
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BHARATBENZ

Course Intent

- This course is designed to educate DSM's, technicians, and anyone else wanting to understand the fundamentals of vehicle vibrations regardless of the Vibration Analyzer used.

- You will be taught how to collect vibration data, rapidly identify the source of the vibration, validate the complaint and more importantly know what is not causing the problem reducing the warranty costs and promoting Uptime.

- You will be provided the component tests and troubleshooting sequence for a specific vibrations classification and order.

Agenda

- Noise, Vibration, & Harshness
- Vibration Characteristics
- Fatigue Due To Vibration
- Drivers Experience
- Drivers Interview
- Primary Sources & Classifications
- Evaluation tools
- EVA/Smart Phone/IPad Set Up, Calibration, & Test Drive
- Vibration Source Diagnostics (Wheel end, Driveline, Engine)
- Service Related Bulletins
- Data Analysis Review

Difference Between Noise, Vibration, & Harshness

- **Noise** – sound heard but not necessarily felt. Noise can be caused by a vibration. Examples would be a rattling shifter which may be caused by improper driveline angles but the result is shifter rattle.

- **Vibration** – repeated movement felt by the driver at the Steering wheel, floor, or seat. Vibration can be measured with an accelerometer and the potential source revealed.

- **Harshness** – a distinct jolt felt by the driver from an input on the road or terrain. It often feels like the suspension is not doing it job. It may be caused by improper ride heights, or worn out components such as suspension components or mounts.

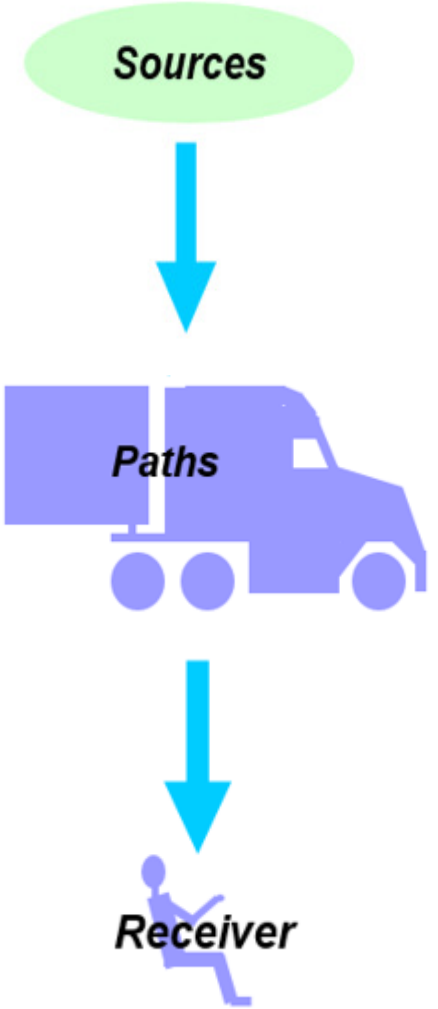
Vibration Basics

All automotive vibrations have 3 basic components

Source – Most of the time it is a rotating component (wheel end, driveline, or engine) component **out-of-round** or **out-of-balance**. Engines have vibrations that are a natural part of an engine running. Transfer paths must be checked first.

Transfer Path – is anything that is connected to, or touches the vibration source. It can be suspension system components, mounts, exhaust system, running boards etc.

Receiver – is the part in or around the cab (occupants compartment) that the driver sees, feels or hears is vibrating. It can be the floor, seat, steering wheel, sun visor, dash mirrors, shifter etc.



Vibration & Measuring Device/Accelerometer

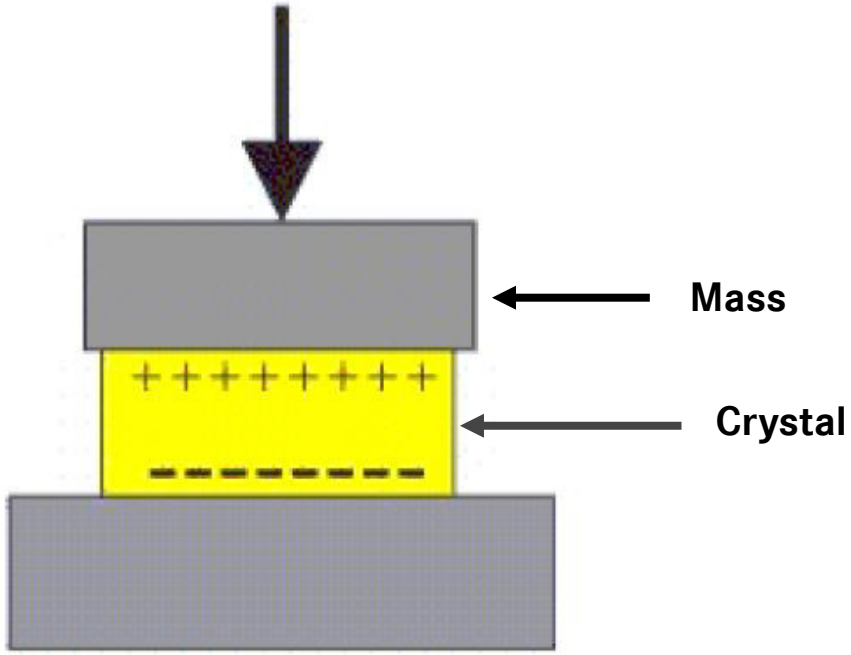
- A **vibration** is a repetitive motion back and forth relative to a fixed central position.

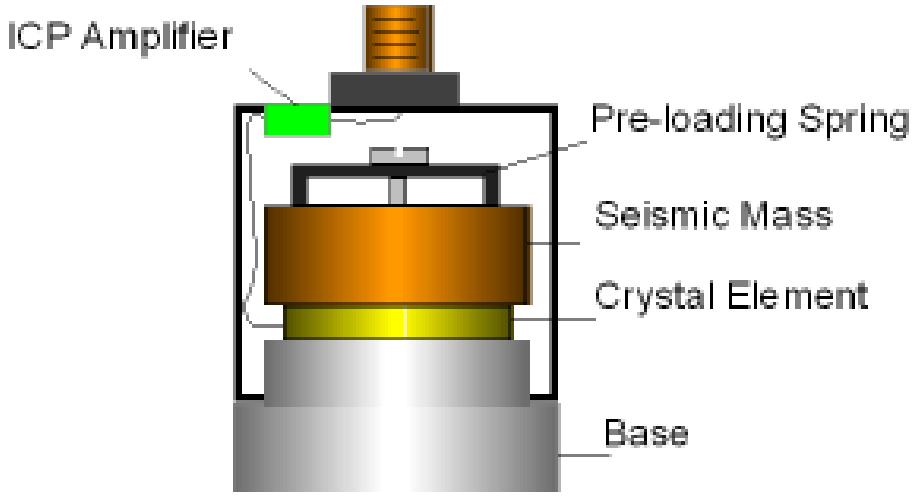
- All truck vibration issues will be due to engine, driveline, or tire orders.

- Vibrations are **measured** by an electromechanical device called an **accelerometer** which measures change in velocity or the force of acceleration caused by gravity or movement over time.

- Accelerometers for vehicle testing are typically a **Piezo-Electric** or **MEMS** type

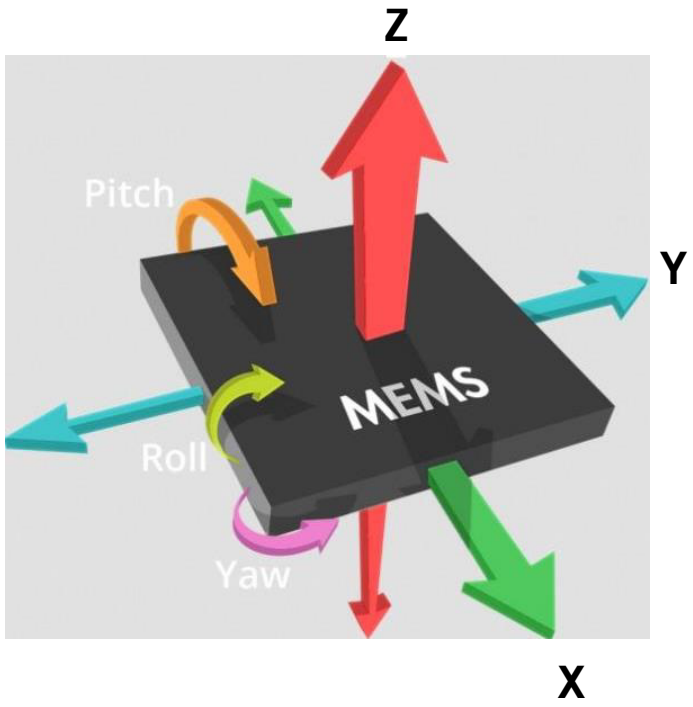
Piezo-Electric Accelerometer

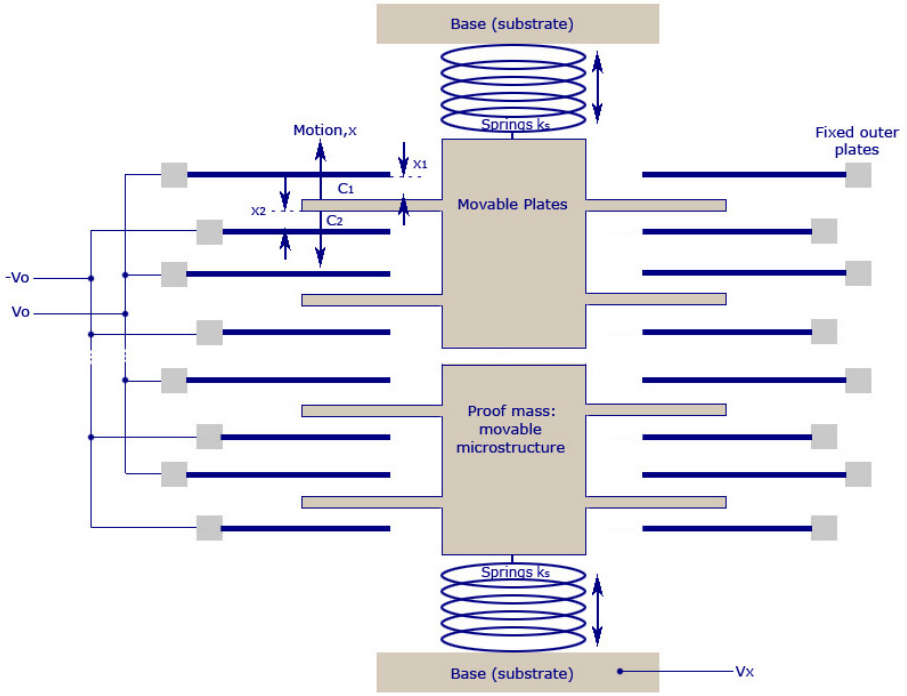


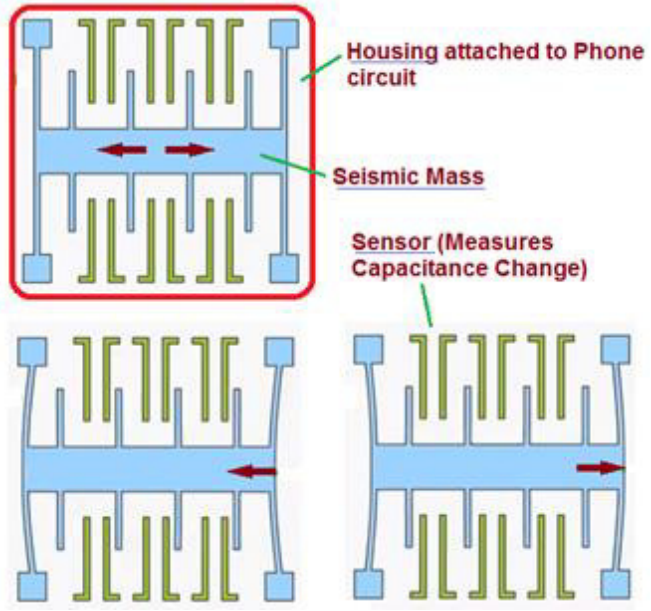


- **Piezo-Electric** are crystal based (man made or natural)
- The basic principle of operation behind a **Piezo-Electric** accelerometer crystals produce a charge when they are compressed, flexed or subjected to shear force. The charge output is converted by electronics.

MEMS Accelerometer







- **MEMS** = Micro-Electro-Mechanical Sensors
- The basic principle of operation behind the **MEMS accelerometer** is the displacement of a small proof mass etched into the silicon surface of the integrated circuit and suspended by small beams.
- Found in Smart Phones can measure all 3 axis as well as pitch, roll and yaw.
- MEMS accelerometer are not affected by temperature and more accurate than a Piezo type

Vibration Characteristics

➢ Vibration Characteristics:

1. **Frequency** is the number of repetitive motions that can be heard or felt in a given **time**, usually in 1 second. The measurement of cycles occurring in one second is called **Hertz (Hz).**

➢ Frequency of rotating components can be determine and calculated by Mathematics.

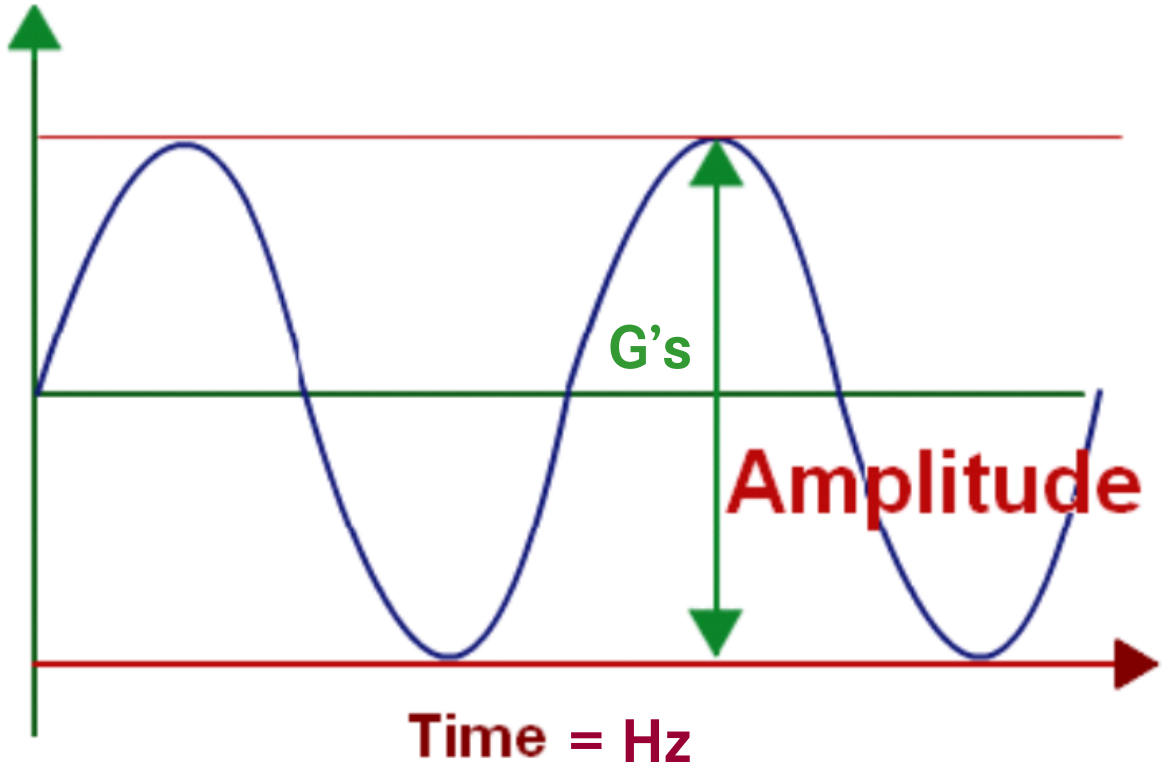
Tire example $\frac{514 \text{ TRPM} \times 70 \text{ mph}}{60 \text{ seconds} \times 60 \text{ minutes}} = 10 \text{ Hz}$

Natural Hz

$\frac{\text{Rear axle ratio} \times \text{Tire Natural Hz}}{3.07 \times 10 \text{ Hz} = 30.7 \text{ Hz @ 70mph}}$ = **Driveshaft Natural Hz**

Vibration Characteristics

2. **<u>Amplitude</u>** is the strength level or severity of the disturbance of the vibration. It is defined as the **distance** from the center of the motion to either extreme. The measurement is in **G's**.



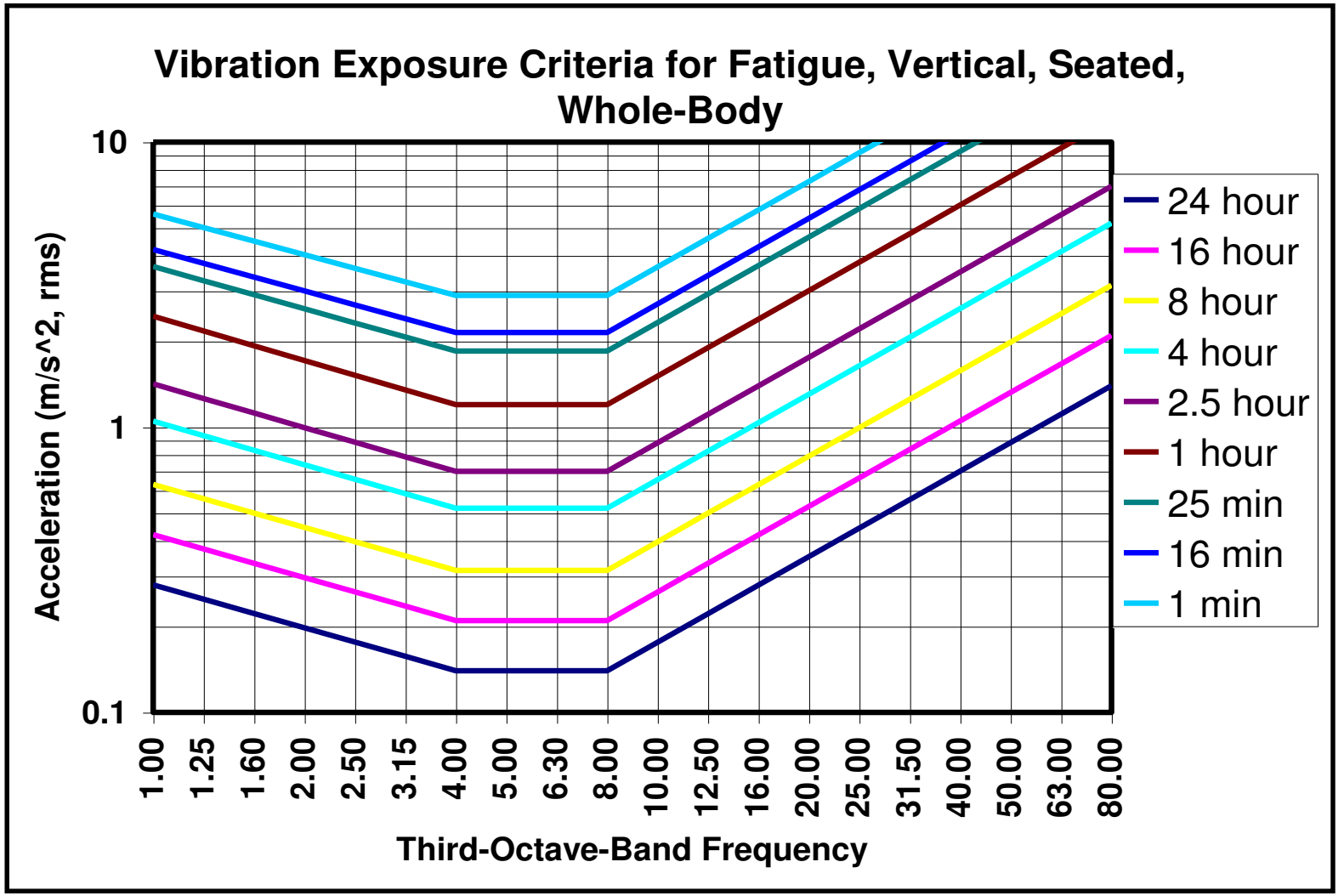
Vibration Characteristics

3. **Resonance** – natural frequency of a component or combination of components (assembly). Resonance amplifies the vibration. When a component is near it's natural frequency it will vibrate at the slightest force. Vehicle applications are designed so that they don't occur during highway cruising speeds.

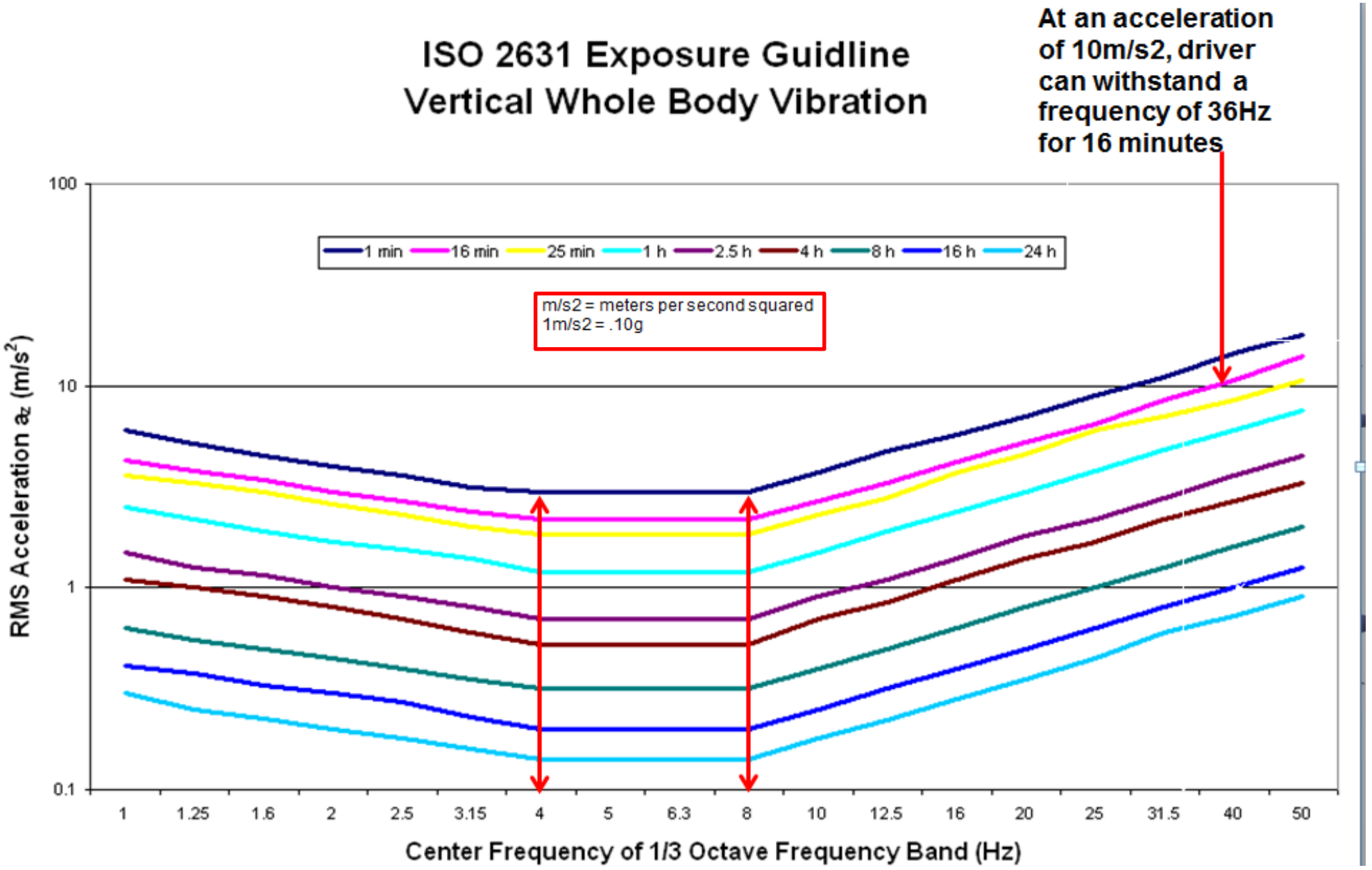
Human Body Sensitivity to Vibration

- Whole body vibration can cause operator fatigue.
- ISO 2631 indicates highest susceptibility is between 4 Hz and 8 Hz.

1 meter/second2 =0.1019g's

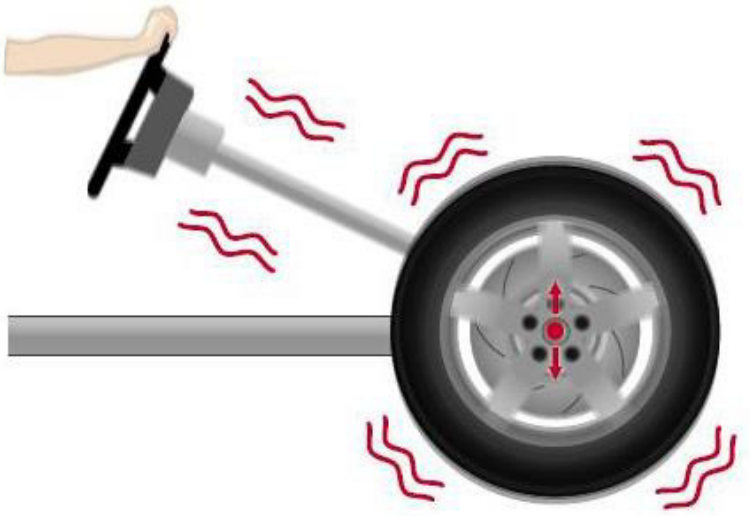


IS0 2631 Exposure Guideline



Drivers Experience to Vibration

- Drivers experience vibration in three ways:
  1. What the driver **feels:**
     a. shaking steering wheel
     b. shaking seat
     c. shaking floor



Note: if the vibration is felt in the steering wheel the source is coming from the front of the vehicle. If the vibration in felt in the floor or seat the source is coming from the rear of the vehicle.

Driver Experience to Vibration

2. What the driver **sees**:
    a. rattling or shaking gear shift lever
    b. shaking mirrors
    c. water or fluid in bottle of cup holder

3. What the driver **hears**:
    a. rattling dash
    b. loose change rattling in cup holder
    c. rattling shifter

Categories of Vibrations

- **Vehicle Speed Related Vibrations**: A vehicle speed related vibration will usually always occur at the vehicle same speed regardless of the engine RPM. This type of vibration cannot be detected with the vehicle stopped.

- **Engine Speed Related Vibrations**: An engine speed related vibration will usually always occur at the same engine RPM speed regardless of the vehicle speed. This type of vibration can usually detected with the vehicle stopped, although sometimes it may only show up under a load.

Drivers Interview

- In order to evaluate the drivers complaint, critical questions need to be ask:

1. **When did the vibration first occur?**
   a. after a component change
   b. since new
   c. check warranty repair history

2. **When is the vibration felt, seen, or heard?**
   a. certain speed
   b. certain rpm
   c. certain road surfaces
   d. does the vibration disappear when the clutch is engaged?

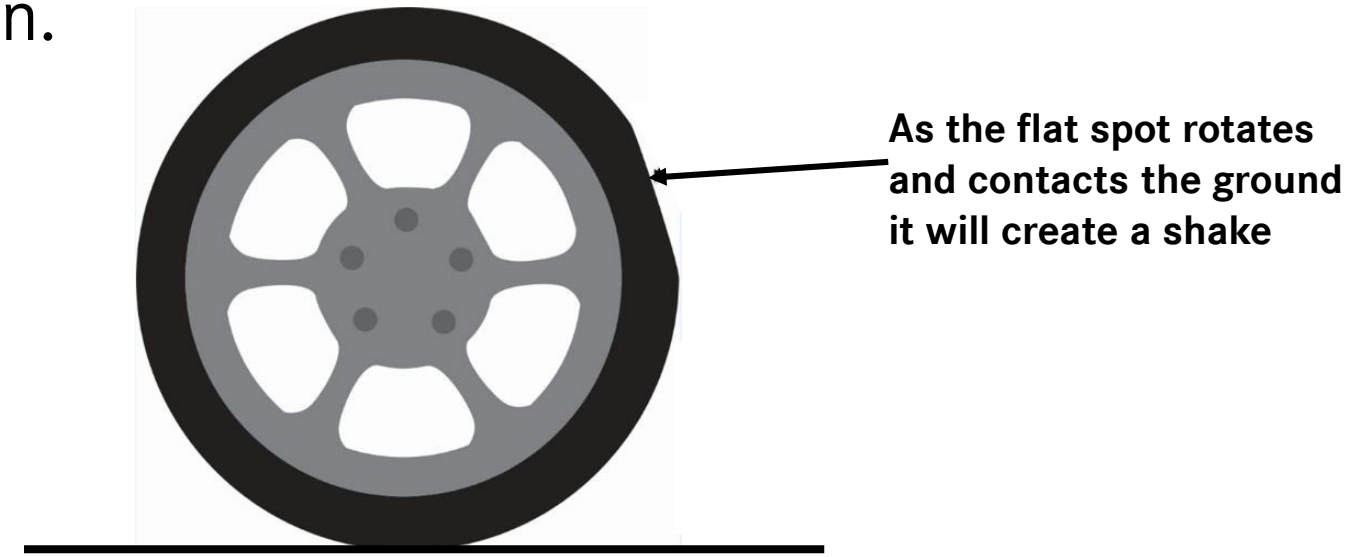
Vibration Questionnaire

VIN # _____ Mileage _____
Customer Name _____
What mileage was the vibration first noticed? _____
Where any repairs made prior to noticing the vibration? Yes ___ No ___
Where is the vibration felt?
Steering Wheel _____
Seat _____
Floor _____
Other _____ explain _____
What speed range is the vibration in MPH? _____
What RPM range is the vibration felt? _____
Does this condition happen in: Bobtail ____ With Trailer ____ Both ___
What type of road surface is the driver experiencing the problem?
Asphalt _____
Concrete _____
Dirt _____
Does the vibration disappear when the clutch pedal is depressed? _____
Is there any visual evidence of leaky transmission output seals? Yes ____ No ____
Is there any visual evidence of leaky differential? Yes____ No ____
Has driver altered the cab or suspension height adjustments? Yes ____ No ____
Has this vehicle been to any other shops for this condition? Yes ____ No ____
Visually inspect tires. Check the item(s) that the tires display.
Under inflation _____
Dry Rot _____
Gouges in tire side wall _____
Wheel damage _____
Chunks Missing out of tread _____
Flat spotted tires _____
Unusual tire wear patterns ____

Vibration Orders & Classifications

- Vibrations are classified into **orders**. Orders are periods which the vibrations occur in relationship per revolution of a component. They are classified as 1st, 2nd, 3rd, 4th, and so on.

- **1st order vibrations** creates one shake per component revolution.
- **1st order vibrations** will always be excessive run out or an out of balance condition.



- **2nd order vibration** creates two shakes per component revolution.

Source of Vibrations by Classifications of Orders

- **Tire/Wheel orders 1st, 2nd, & 3rd**
  causes: Wheels, hubs, drums, rotors and tire assemblies
- **Driveline or Propeller shaft 1st order**
  causes: Drive shaft, park brake drums, yokes & phasing
- **Driveline or Propeller shaft 2nd order**
  causes: U-joints, phasing, working angles, dynamic bearing load
- **Engine orders**
  causes: Engine mounts, exhaust, crankshaft, dampers, etc.
- The trend of conditions is over a 15 year period
  Tire/Wheel End (90%)
  Driveline/Drive train (8%)
  Engine/Exhaust (2%)

Vibration Analysis & Confirmation

- Before Test Driving vehicle make sure the tires are inflated to the proper specification
- Make sure suspension and cab air ride height are set correctly.
- Inspect the driveline to make sure vehicle is safe to drive.
- Test drive the vehicle using a reputable Vibration Analyzer to validate & identify the source and classify the order of the vibration.
- Sometimes preparing the vehicle fixes the problem

Evaluation Tools

- Vibration Analyzer tools will minimize troubleshooting time.

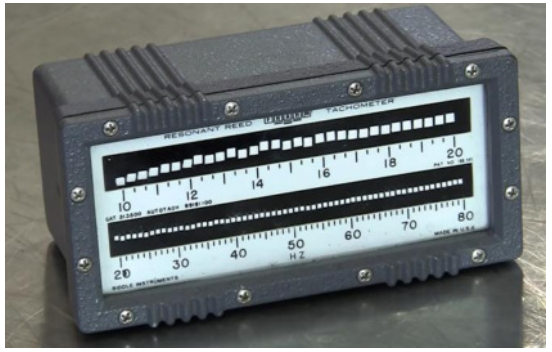
- If using a tool such a the Kent Moore EVA (**J-38792-A**) Vibration Software (**J-38792-VS**) will also be needed to locate and identify the primary source of vibration.

- Always make sure the most current operating software is used Kent Moore EVA is Version 3.0 memory cartridge Kent-Moore part # J-38792-60.

- Other Vibration analyzing tools are the MTS 4100, Eaton DVA MD-300, or Smart Phone such as IPhone with appropriate vibration software app.

Vibration Evaluation Tools

Sirometer



Resonant Reed Tachometer

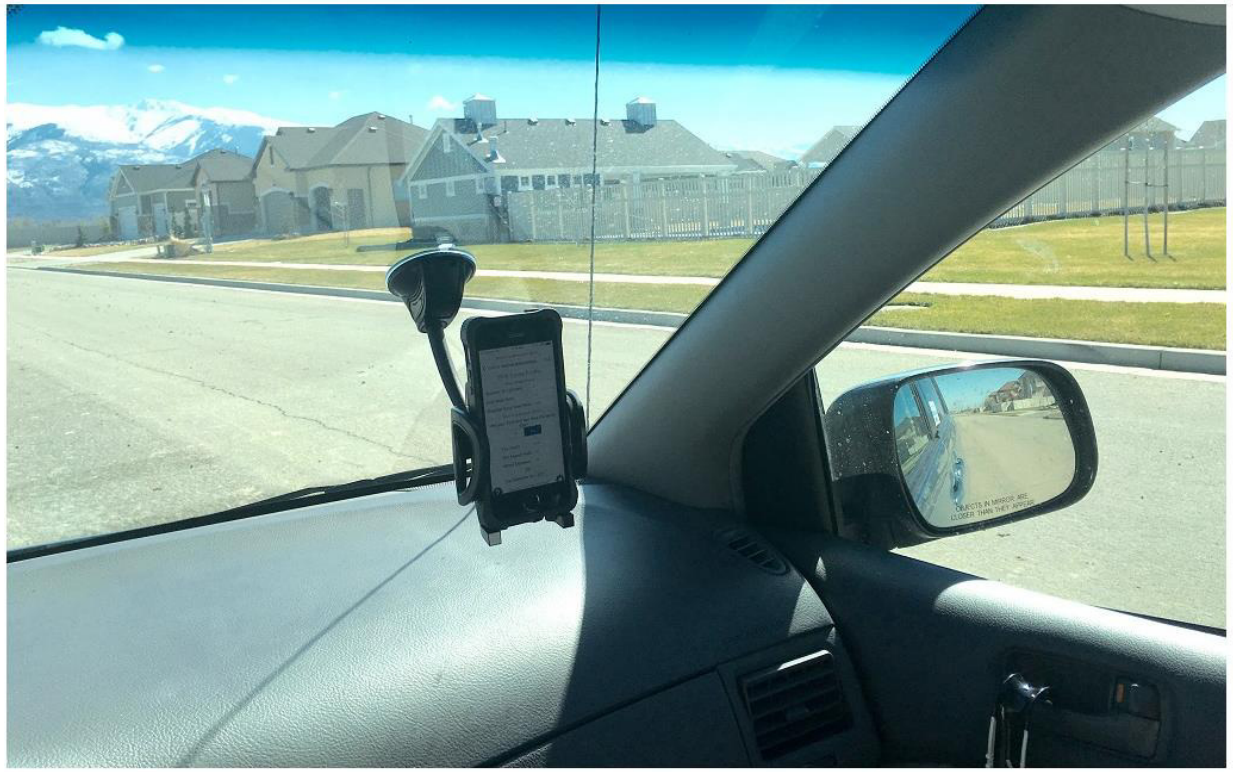
Kent Moore EVA2

MTS 4100

Eaton DVA MD-300

Picoscope NVH Kits

Vibration Evaluation Tools Smart Phone for Vibration Diagnosis



Side Glass Suction Cup Mounting Example. Move to any window in the vehicle to detect or isolate the vibration. WARNING: Do not block the driver's view of the road or of the rear view mirrors.

- Phone with NVH App can be used to locate the Vibration order
- Set Up and Use will be covered later in this presentation

Vibration Evaluation Tools

Tool	Advantage	Disadvantage
Sirometer	In expensive, easy to use	Limited usage, doesn't register g's, no accelerometer
Resonant Reed Tachometer	Easy to use	Expensive, hard to find, limited usage
Kent-Moore EVA2	Easy to use, can adjust sensitivity and average over a period of time	No longer sold, single axis accelerometer, rounds up the g's, doesn't indicate source need separate software, requires separate RPM monitoring
MTS-4100	Indicates source	Expensive, single axis accelerometer, doesn't support all data links.
Eaton DVA MD-300	Nice Graphics, Also displays torsionals	Expensive, long time to set up, doesn't work with non J1939 Vehicles, doesn't indicate source need separate software
Pico Oscilloscope	Nice Graphics, indicates source	Takes 4 separate pieces to work, Laptop, RPM from datalink, Scope, and NVH Interface
NVH Smart Phone App	Most accurate accelerometer, Tri-axis mems accelerometer, very portable, indicates source, can adjust sensitivity	Can not easily mount to specific test points around the vehicle. Issue should be resolved when blue tooth accelerometer is available. Mem accelerometers are very sensitive compared to piezo electric types

Vibration Worksheet

➢ Troubleshooting using the EVA

Prepare the vehicle
Prepare worksheet/Accelerometer Data Collection form
Prepare EVA tool

Accelerometer Data Collection Form

Customer JB Hunt **Date** 8/15/14
VIN # N92199_____ **Engine**_____
Model_____ **Mileage**_____
Complaint Vibration felt in driver seat 55 – 70 mph
Vehicle Complaint Start Speed or RPM 55 mph
Vehicle Complaint End Speed or RPM 70 mph

Speed	RPM'S	HZ	G's	Sensor Location
55	1200	8	.07	seat base
60	1500	10	.10	seat base
65	1800	12	.10	seat base
70	2100	14	.10	seat base

Rear Axle Ratio 3.42 **Transmission Top Gear ratio** .73

Kent Moore EVA: Setup/Calibration

- Connect Tool to power source with vehicle not running.
- Calibrate accelerometer/s
- Select Channel to which accelerometer is attached (A or B).
- Place tool in normal mode.
- Place accelerometer on flat surface (seat base) with the word “UP” facing upwards.
- **Push ↑ or # 1** to initiate **then 2-2-2** (follow instructions on screen)
- If using 2 accelerometers repeat procedure on second accelerometer.
- Put EVA into Average mode.
- Put into Hz mode.

Kent Moore EVA Tool Buttons & Functions

- The Kent Moore EVA has specific buttons and functions you will need to become familiar with.
  - Averaging Mode
  - Freeze
  - A & B
  - Strobe (when used with accessory)

Accelerometer Placement & Test Ride

- Always start Analyzer measurement at driver seat base
- Frame data has no pertinence to complaint validation process.
- Accelerometer can moved to other areas and can be secured by the magnetic base to ferrous components, and velcro, or putty to non ferrous components. It needs to be on a hard surface.
- Conduct road test using EVA and Accelerometer Data Collection Form
- Record findings from EVA tool onto Data Form
- Validate the source and classify the vibration by test driving the vehicle with the driver if possible.
- Have the driver operate the vehicle at the speed the vibration is most noticed.
- Operate Flat surface, steady speed, not up or down hill, cruise control with tool in average mode for several minutes if possible
- On MTS4100 or Phone App review findings to locate source and validate severity

Evaluation Test Ride

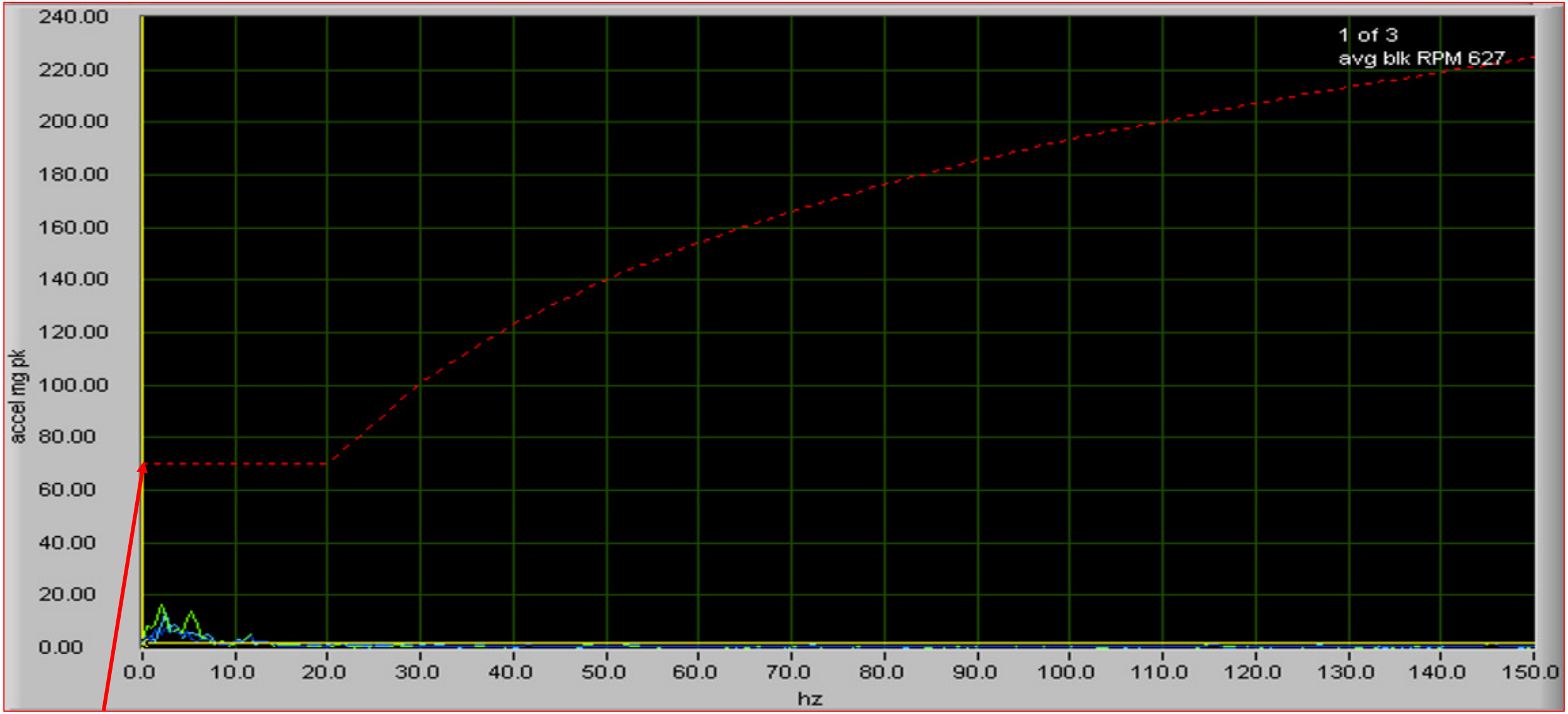
- ***Do not make comments regarding the alleged vibration. Let the tool indicate whether there is an issue or not.***

- It is important to confirm valid complaints, however, validating a customer concern or observation may be admitting to a problem when one does not exist. Certain vehicle configurations have different ride characteristics. Make sure your not trying to fix a good vehicle.

Vibration Guidelines/Standards

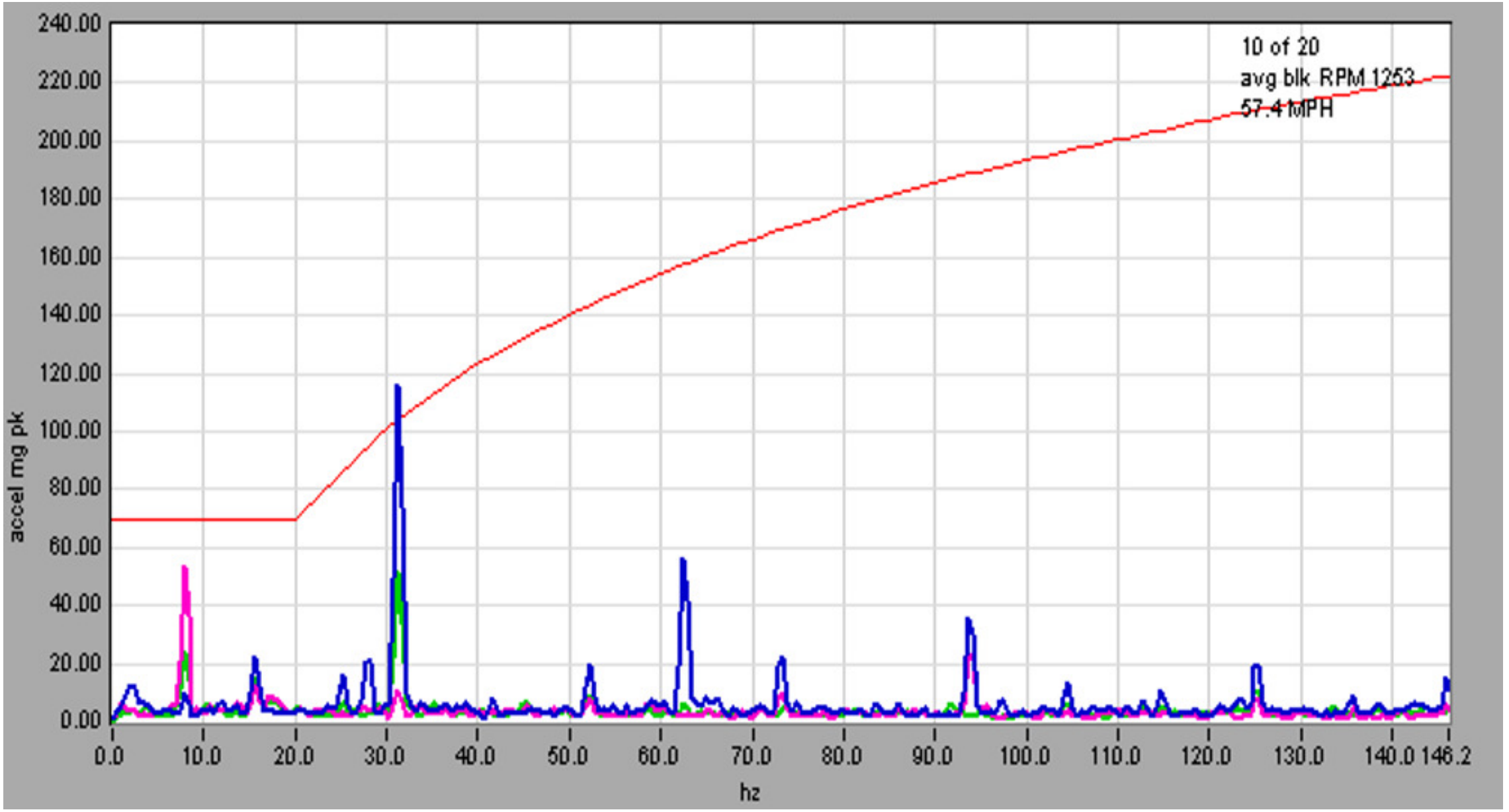
- All vehicles vibrate to a certain level
- Amplitudes of 0.06G's in the occupants compartments such as the cab or sleeping area are commonly acceptable to drivers and passengers.
- Amplitudes higher than the baseline chart in the cab or sleeping area need to be addressed

ISO Baseline Chart



Note: 70.00 mg pk = .07g amplitude
mg pk = milli g's peak kinetic

ISO Baseline Chart



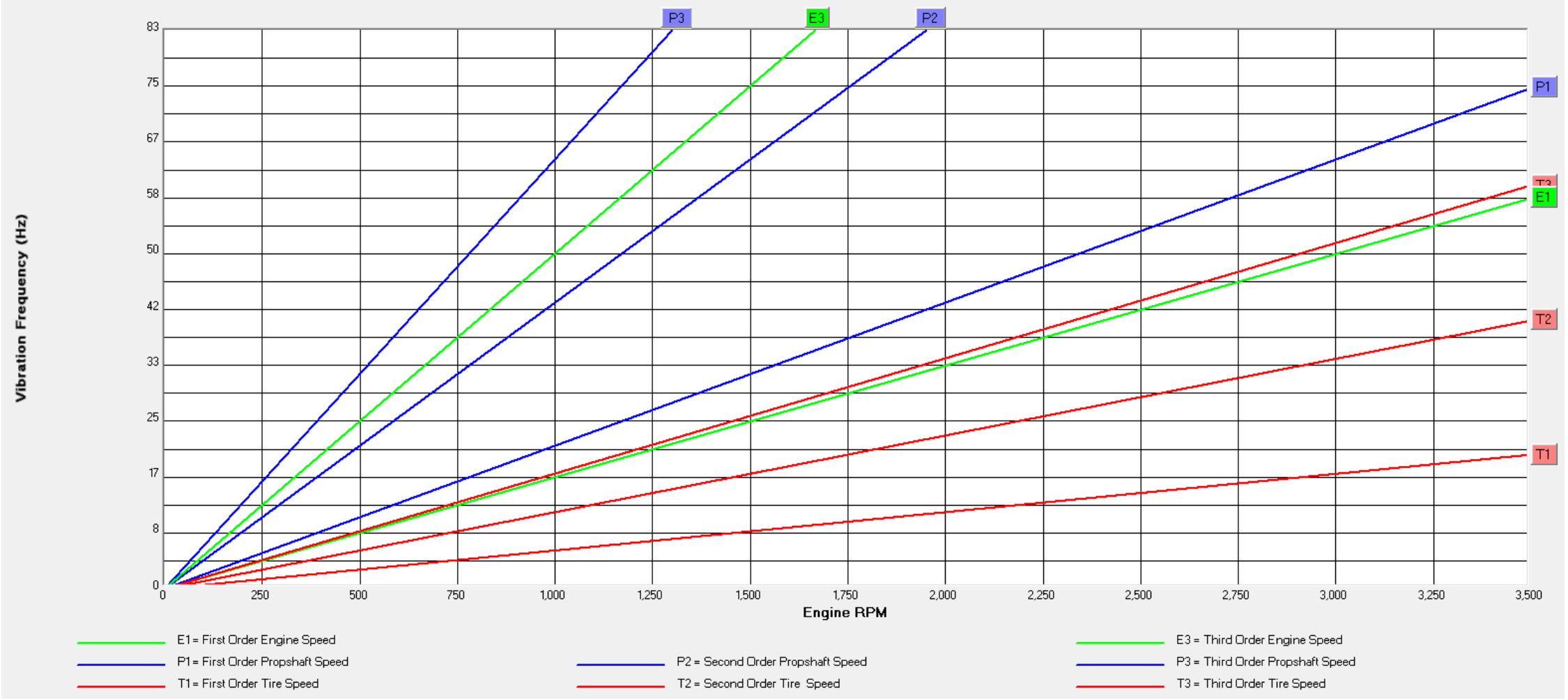
Tool Analysis

- If readings are higher than the ISO baseline chart use Vibrate 5.1 software or let tool locate the source.
- Depending on the Vibration Analyzer or software used, you will need to set it up some of the following information will be necessary:

  - **Rear Axle Ratio**
  - **Transmission Gear Ratios (usually top gear)**
  - **Number of Engine Cylinders**
  - **Average mode and length of averaging**
  - **Amplitude Sensitivity**

Vibrate 5.1 Software

- **Vibrate 5.1** Kent-Moore **Part # J 38792-VS** is a computer software program used in support of Vibration Analyzers to help determine the source of a vibration concern. **www.vibratesoftware.com**.
- **Give Demo** on How to use 5.1 Software



iPhone App Electronic Vibration Analyzer

- Search for “Vibration Diagnosis” on iPhone and download app.
- All you need is iPhone app for vehicle diagnosis
- Bluetooth accelerometer is due out the summer of 2018 for advanced remote diagnosis
- For engine diagnosis there is a blue tooth datalink adapter that plugs into the diagnostic connector to obtain accurate RPM critical for diagnosing engine related issues.

Smart Phone or IPad Set Up

NVH App Diagnostic Procedure

Preparing for a Road Test

IMPORTANT: When Road Testing a vehicle the following precautions should be taken:

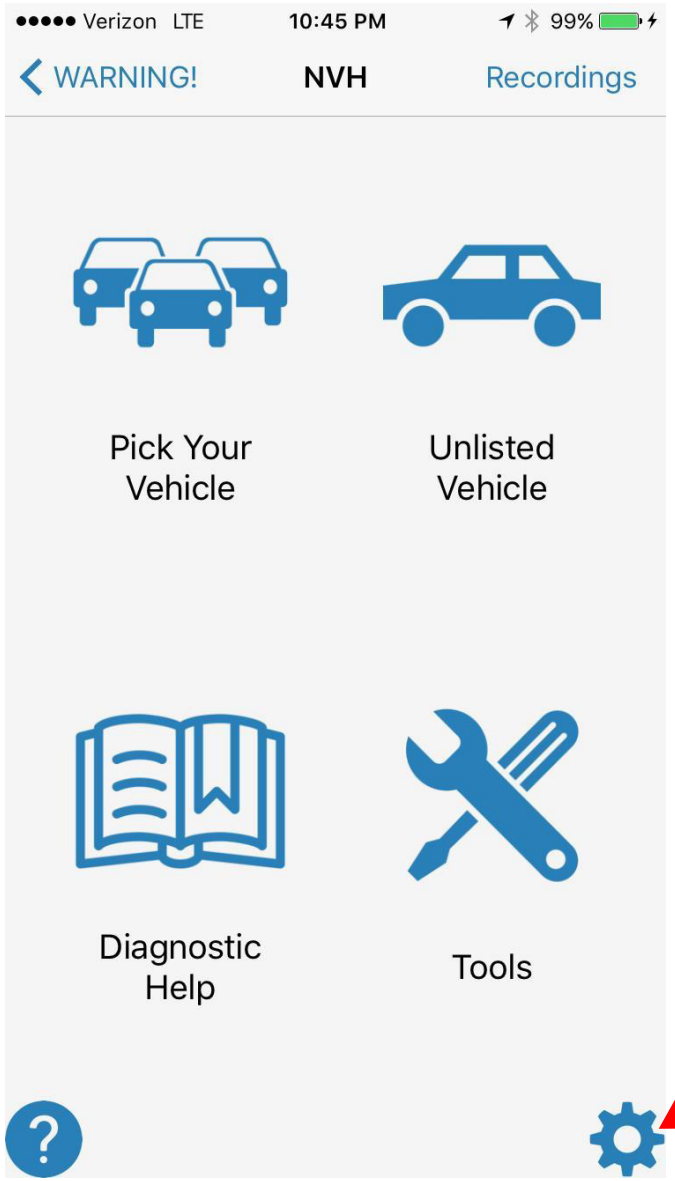
1. Determine if your vehicle may require the optional **Bluetooth data link adapter** to diagnose engine speed related vibrations by reading the Tools Needed information.
2. Visually inspect the vehicle to make sure it is safe to drive.
    1. Look at the tires, make sure they do not have any visible bulges and have adequate tread.
    2. Make sure your tires are inflated to the correct air pressure (see the tire label on the door post with the driver's door open for the recommended tire air pressures). Low tire pressures can cause vehicle vibrations due to excessive tire sidewall flexing.
3. Road Test the vehicle on a smooth level road.
4. A steady throttle must be held to obtain accurate readings on vehicles equipped with an automatic transmission. This will keep torque converter clutch slippage to a minimum. Use Cruise Control if possible.
5. Never place the iPhone or iPad* in a location that blocks the driver's view of the road or of the rear view mirrors. Always educate yourself of state and local laws and regulations regarding windshield and front seat side glass mounted devices.
6. Educate yourself with the basics of vehicle vibrations and terminology by studying the Vibration Diagnosis School page.

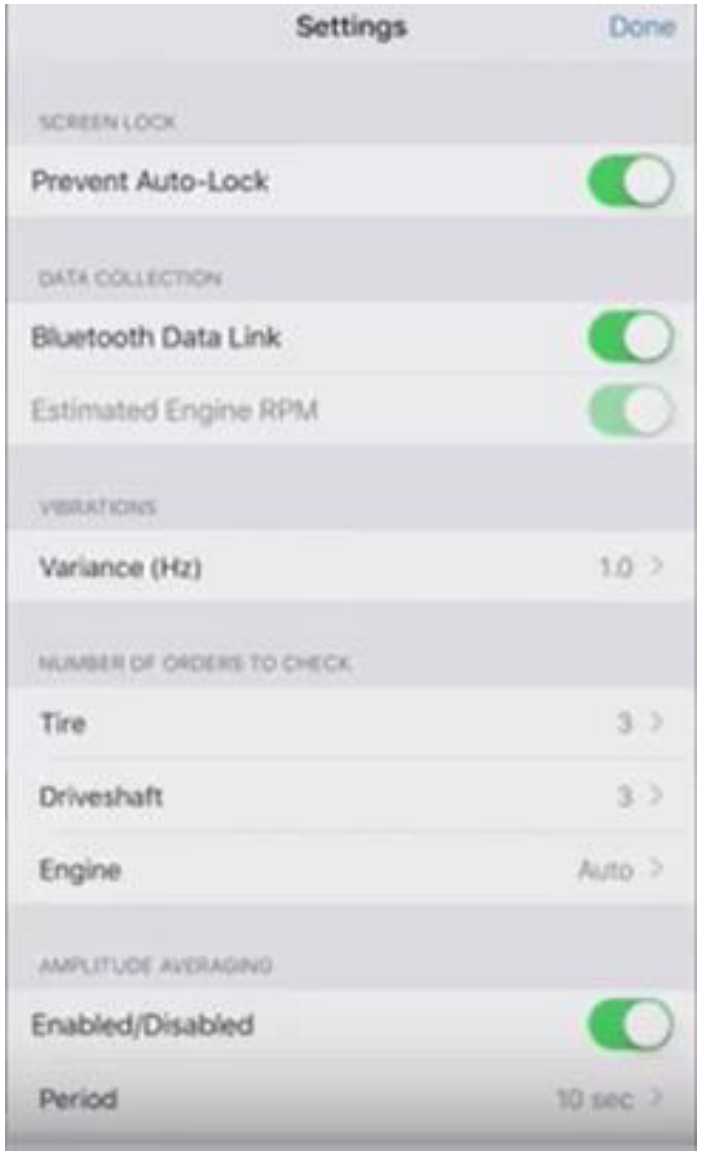
Smart Phone or IPad Set Up Continued

One Time Initial NVH App Setup

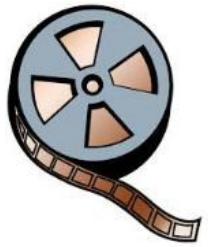
1. If using the optional Bluetooth data link adapter, plug it in to the data link connector under the instrument panel on the driver's side. Then enable Bluetooth Data Link in the Settings Screen.
2. It is recommended that you close all other open applications by double pressing your home button and swiping upwards on the screen on all open apps.
3. Receiving or placing a phone call and many other app alerts may interrupt the data recording. If an interruption occurs, a prompt to continue recording will be displayed; just select continue to keep recording. On apps with Notifications enabled, if you change your iPhone or iPad* app alert styles to banners (or None) instead of Alerts, notifications will not interrupt your recording. Select Settings, then Notifications, then scroll down the list of your apps. Look for any that have the word "Alert" in the notification style. Select the app and change the alert style to banner (see screen shot below).
4. A power adapter is recommended to help maintain the iPhone or iPad* battery level while using this app since the screen Auto-lock feature is disabled by default. This setting can be adjusted in the Settings Screen.
5. Start the NVH app and select **Pick your Vehicle** from the main menu and follow the prompts at the top of the screen.
6. If your vehicle is not in the list of supported vehicles, select **Unlisted Vehicle** and follow the prompts at the top of the screen.
7. Find an assistant to drive the vehicle while you perform diagnostics with your iPhone or iPad* from a front or rear passenger seat position.
8. Place your iPhone or iPad* on a solid surface like the dashboard, floor, or center console. Alternately you can place it in a windshield or side glass suction cup attachment. NOTE: It may be necessary to move the iPhone or iPad* to other locations inside the vehicle to obtain good diagnostic readings. For example, If you can feel a vibration, but the NVH app is not displaying any diagnostic results, move the iPhone or iPad* to another location closer to where you can feel the vibration.

Set Up for NVH IPhone App



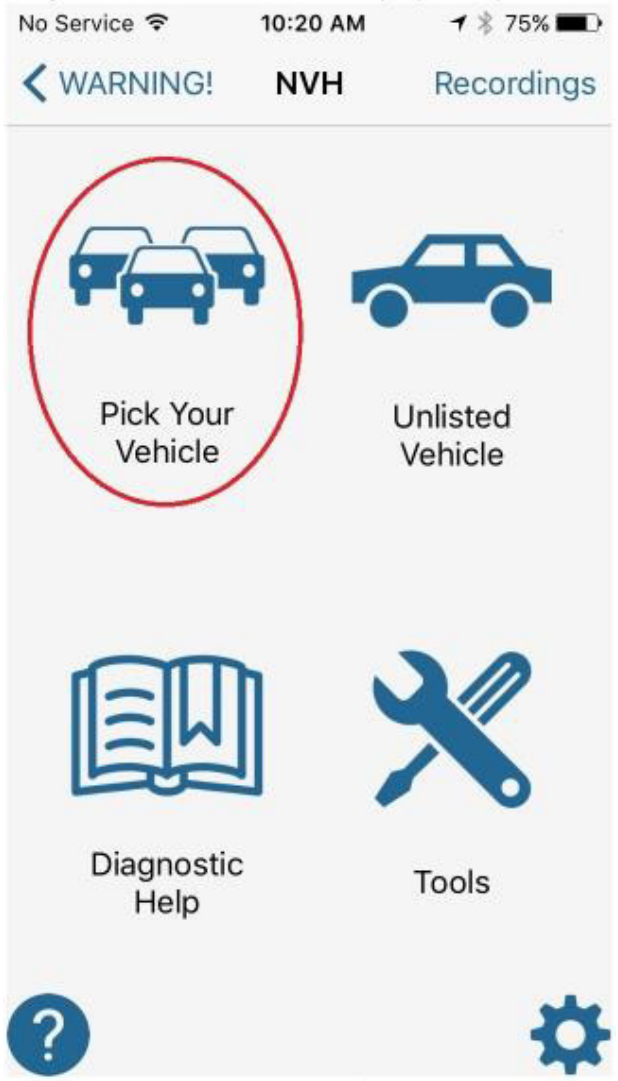


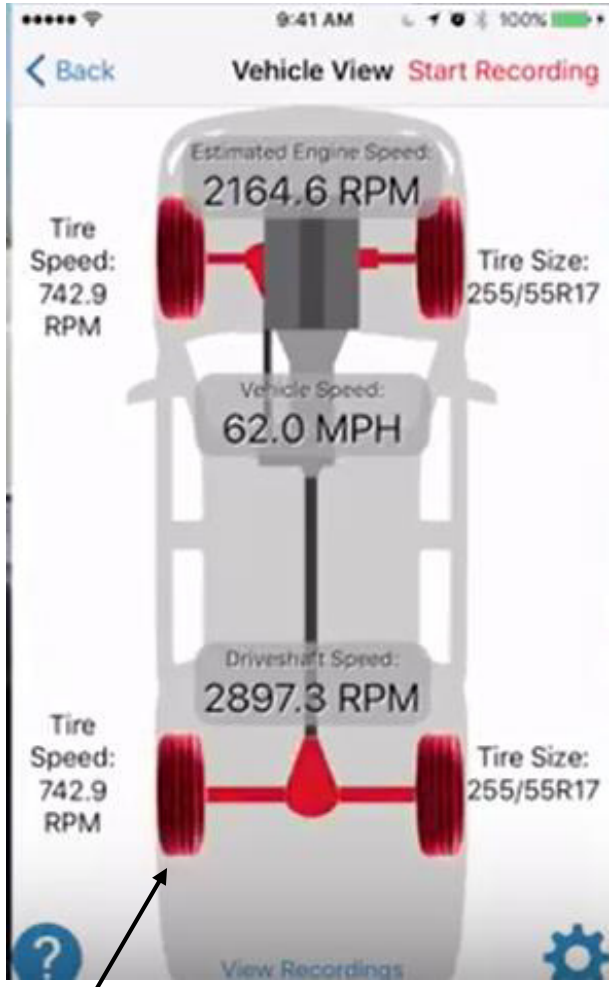
- **Settings allow the following:**
- - Connect Blue Tooth Data Link
- - Vibration Variance (Hz)
- - Number of Orders up to 6
- - Amplitude Averaging up to 30 sec.
- - Amplitude Sensitivity up to 0.0001
- - Vibration Frequency Hz or CPM
- - Vehicle Speed MPH 0r KPH
- - Tire Diameter inches or mm
- - Good Staring point for Amplitude Averaging is 10 sec and Amplitude sensitivity threshold 0.01.



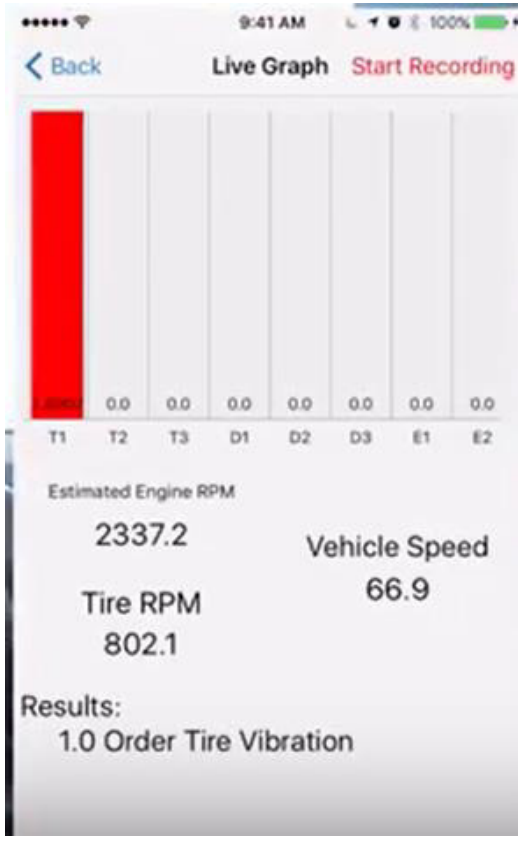
Road Test Using App

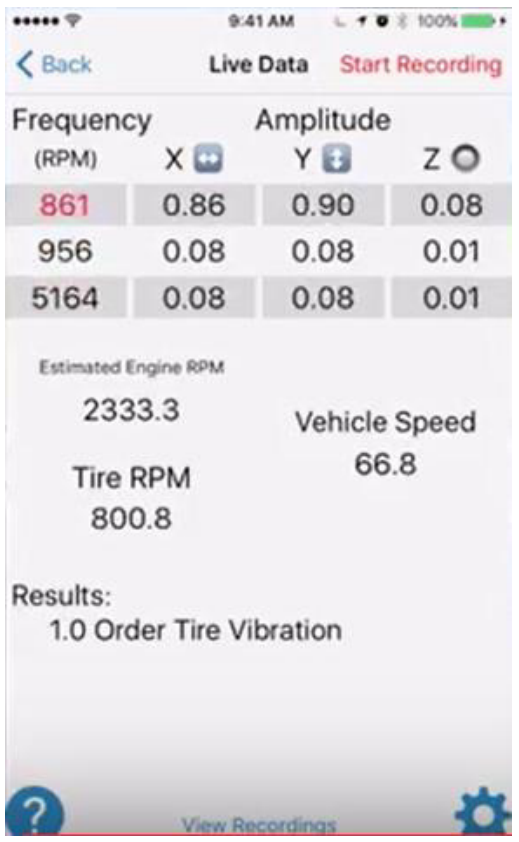
Smart Phone or IPad Set Up Continued





In vehicle view items in **"red"** light up if there is an issue



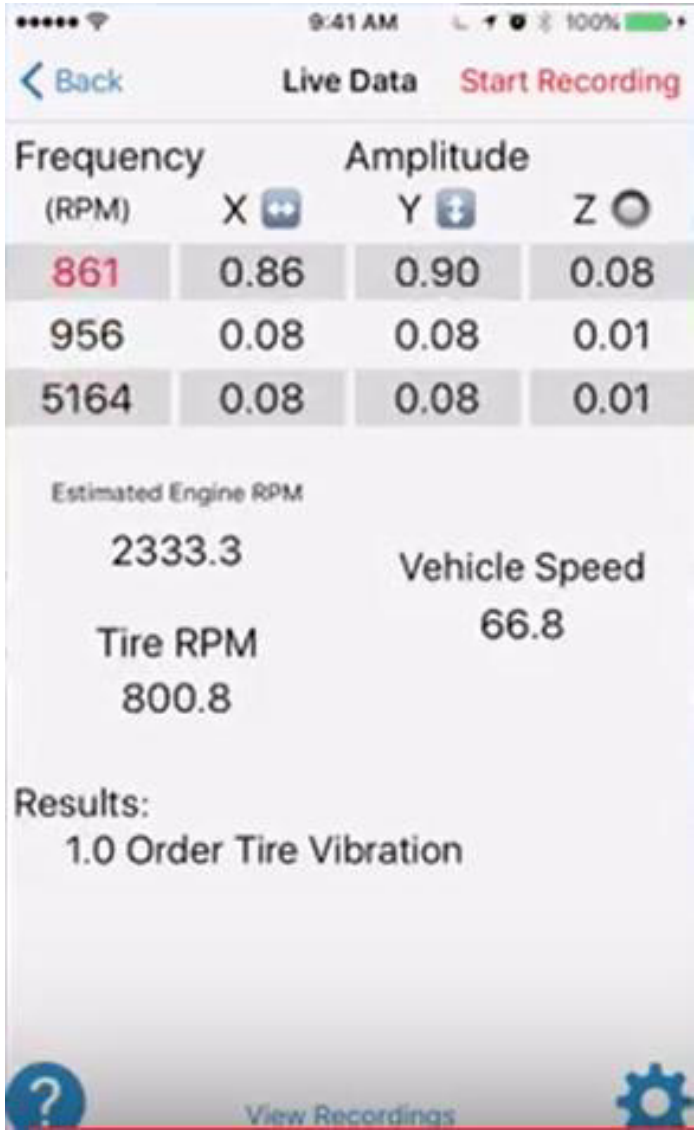


https://youtu.be/s1cr3QaOzGY How to use

https://youtu.be/VXfMghCyzGk Engine

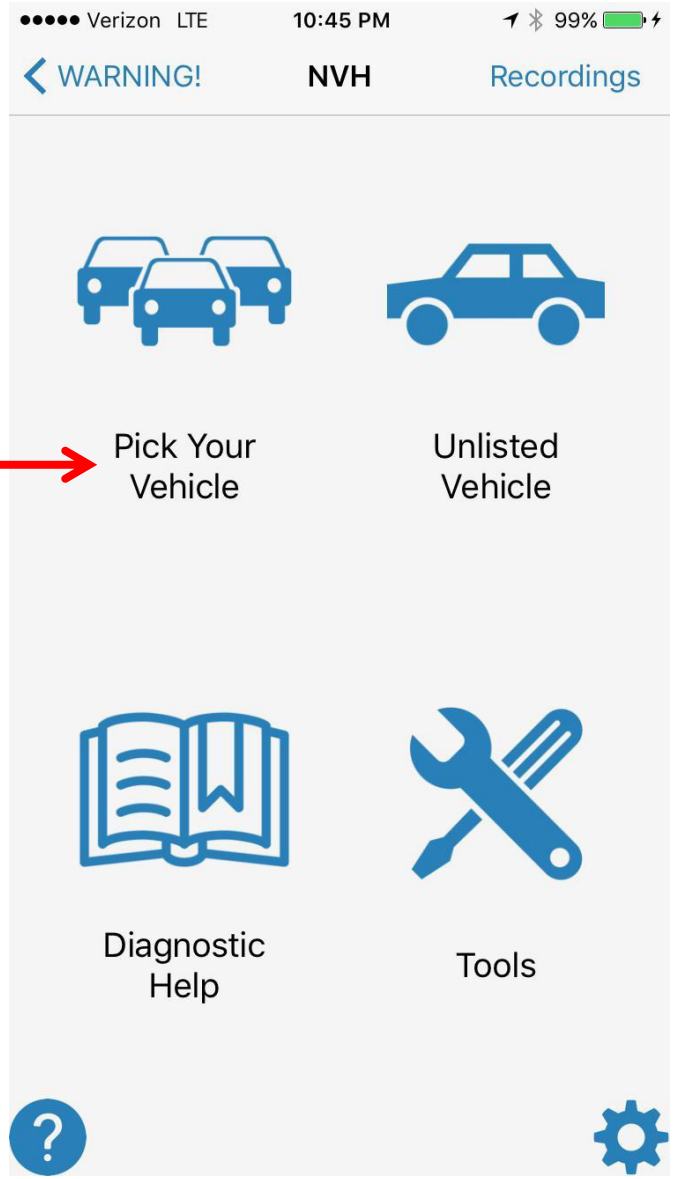
https://youtu.be/GuI0hH2TuxQ Driveline

Vibration Orientation for Live Data Screen



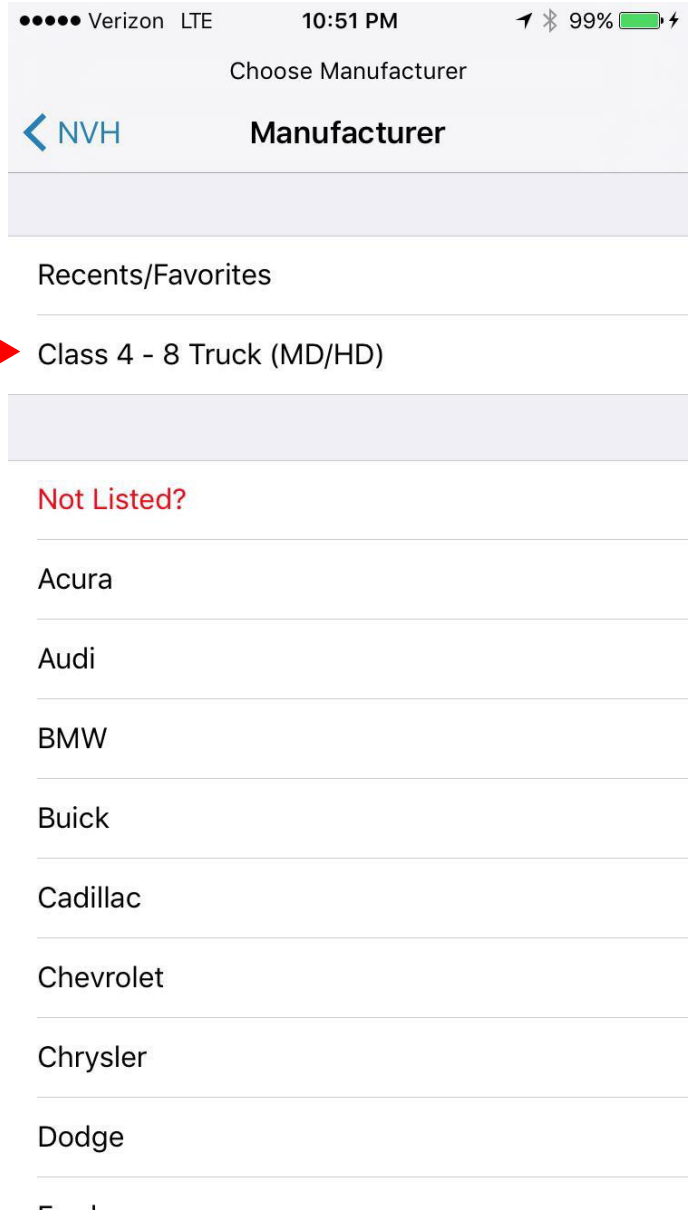
X = Fore & Aft
Y = Left to Right
Z = Up and Down

Example VIN: GF1913

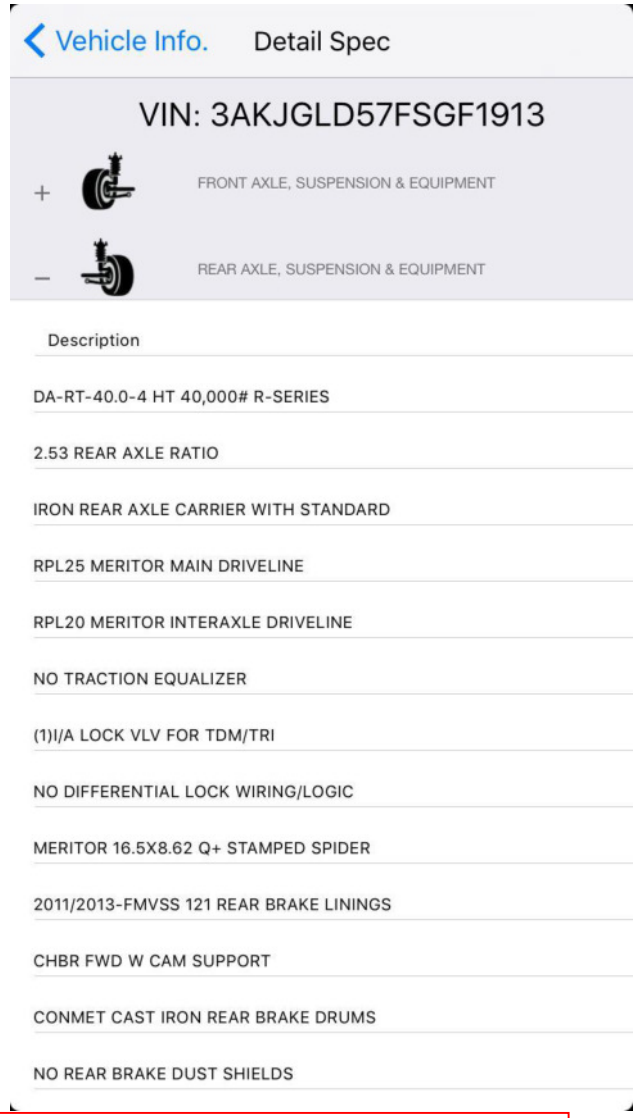


Click Here →

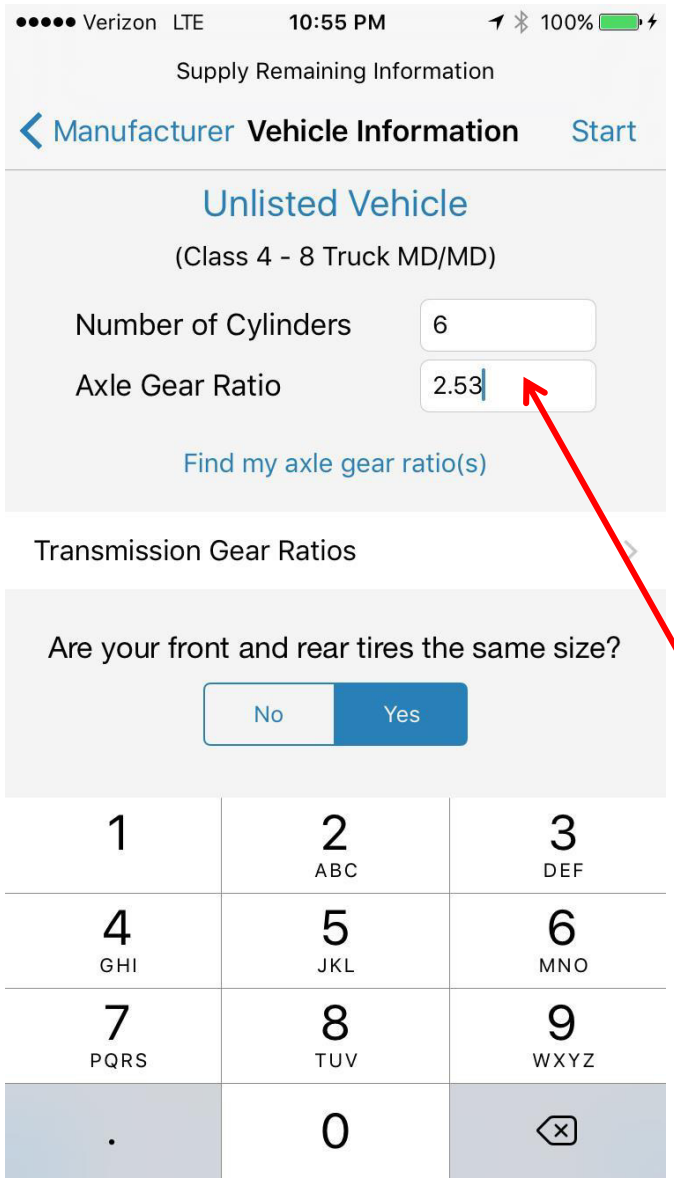
Then Here →



Use (Uptime Pro Mobile) App to find gear ratio and transmission type.

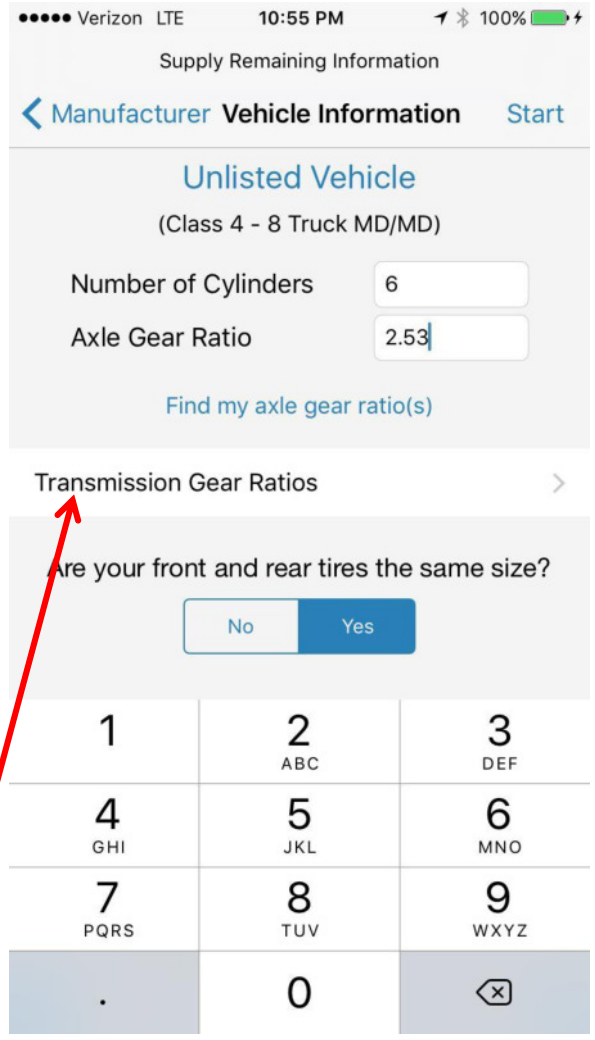


Xpress Write up App



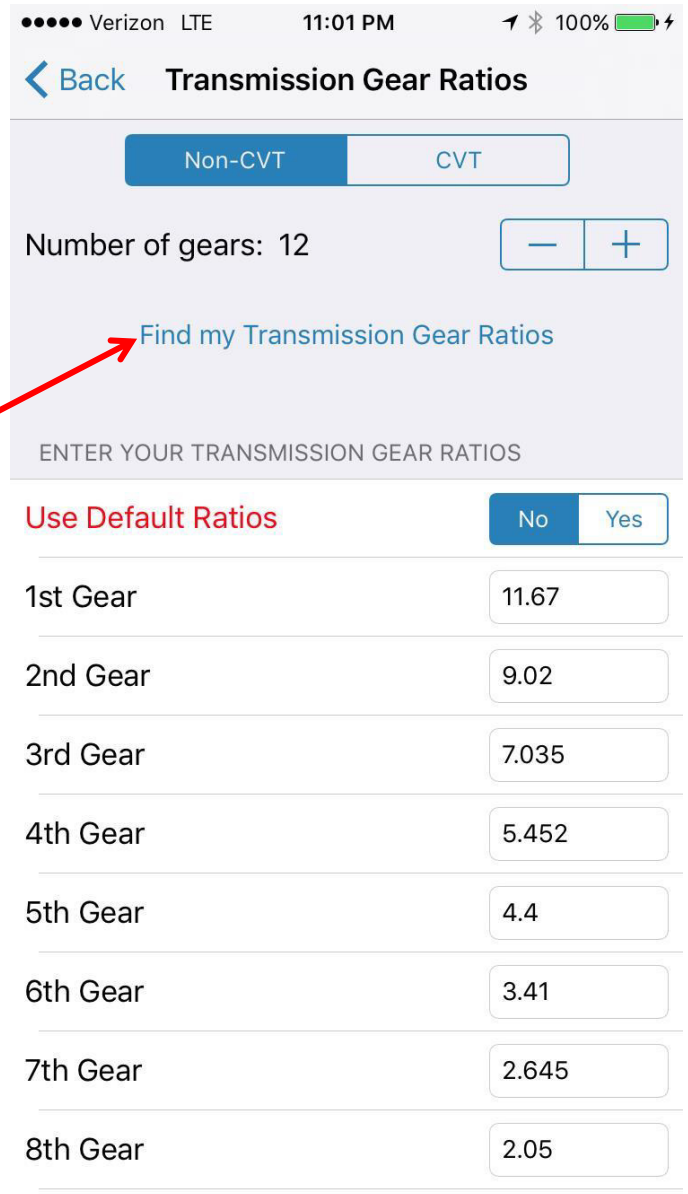
Enter Info Here

Enter Transmission Gear Ratios

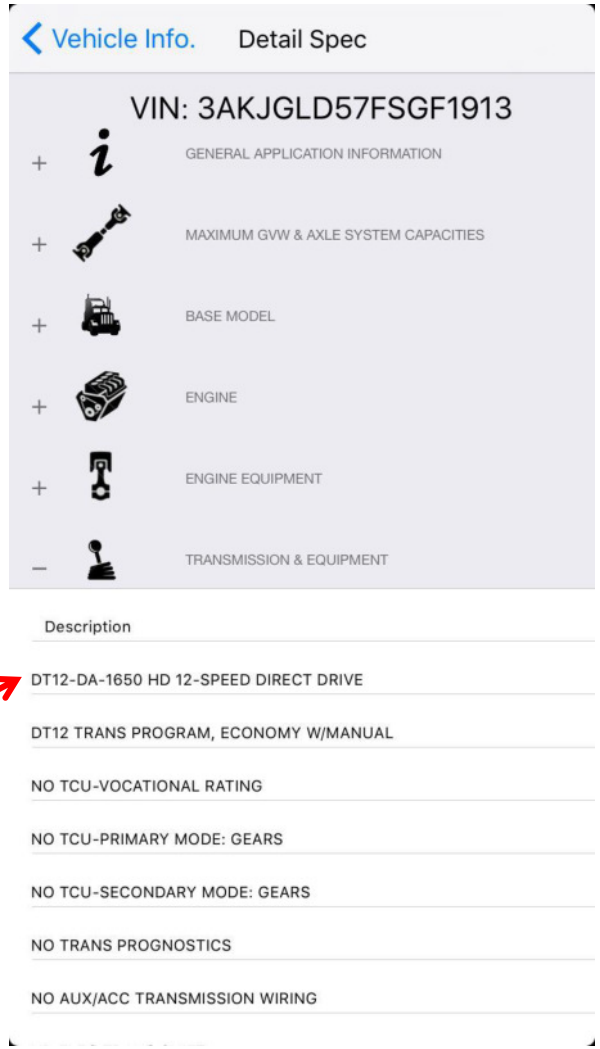


Click Here

Then Here



Use Express Write Up to Find Transmission Type

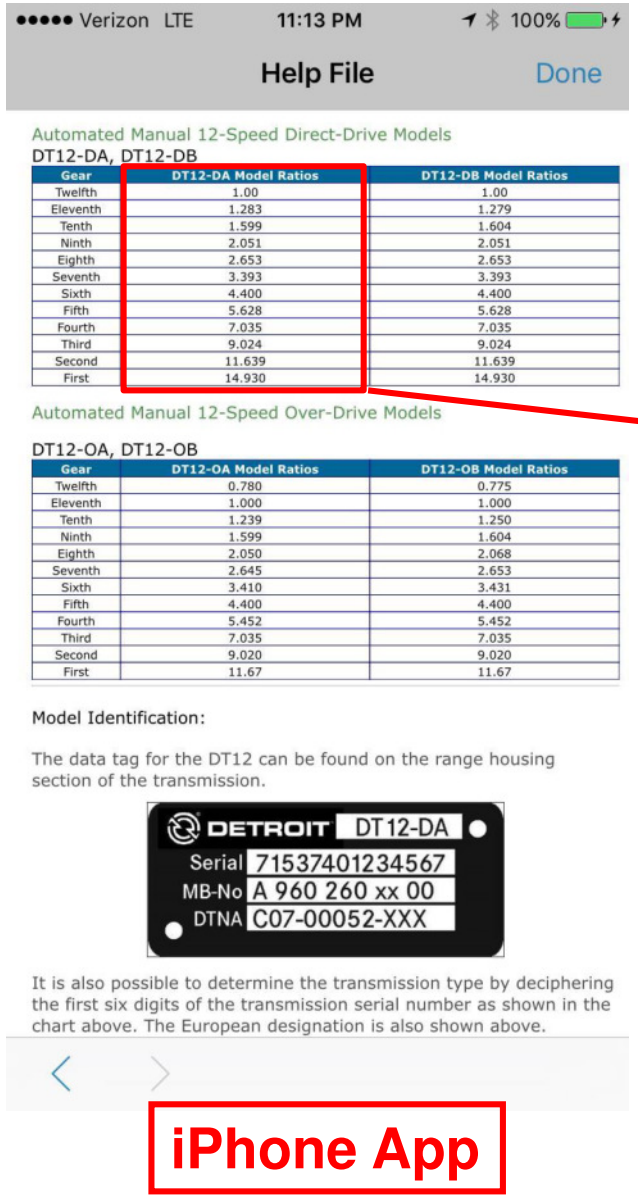


Express Write Up

Click Here

iPhone App

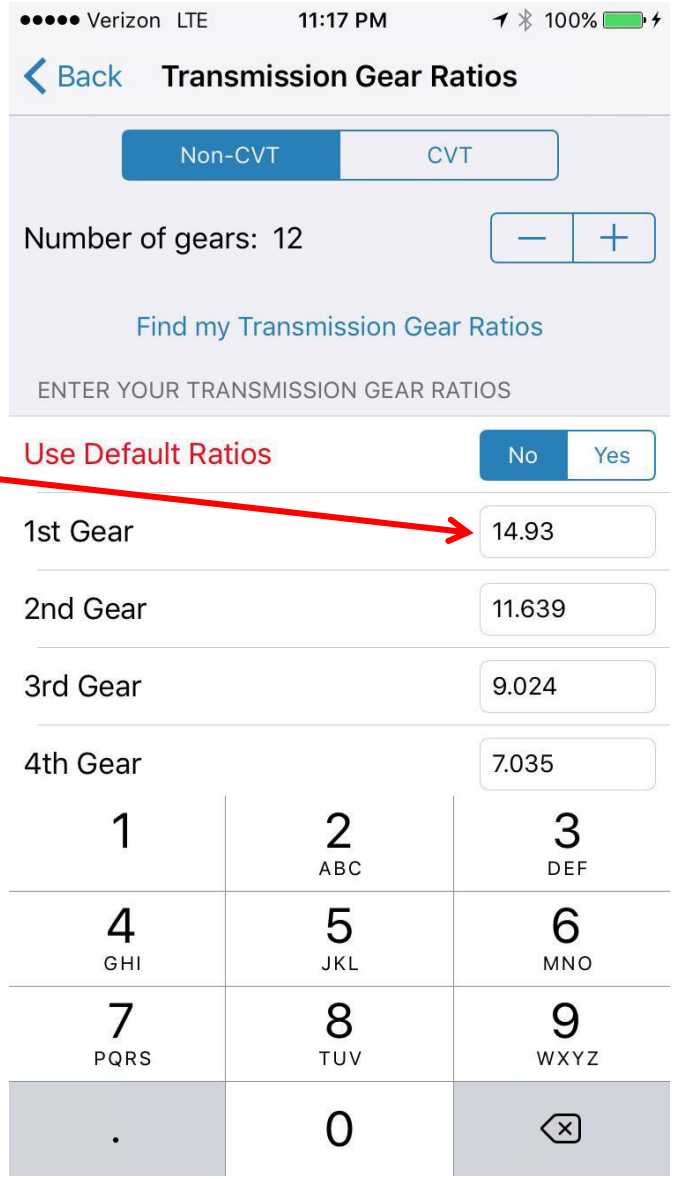
Record ratios and then type in all gear ratios into App, then hit “back.”



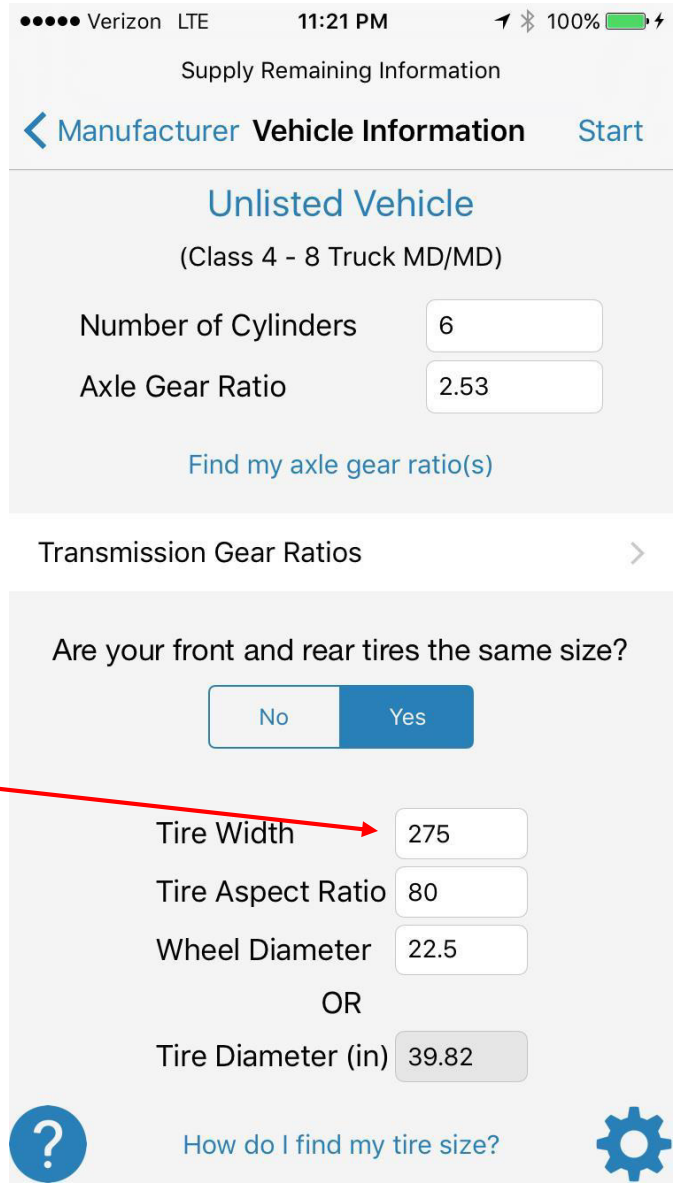
Gear	DT12-DA Model Ratios	DT12-DB Model Ratios
Twelfth	1.00	1.00
Eleventh	1.283	1.279
Tenth	1.599	1.604
Ninth	2.051	2.051
Eighth	2.653	2.653
Seventh	3.393	3.393
Sixth	4.400	4.400
Fifth	5.628	5.628
Fourth	7.035	7.035
Third	9.024	9.024
Second	11.639	11.639
First	14.930	14.930

Gear	DT12-OA Model Ratios	DT12-OB Model Ratios
Twelfth	0.780	0.775
Eleventh	1.000	1.000
Tenth	1.239	1.250
Ninth	1.599	1.604
Eighth	2.050	2.068
Seventh	2.645	2.653
Sixth	3.410	3.431
Fifth	4.400	4.400
Fourth	5.452	5.452
Third	7.035	7.035
Second	9.020	9.020
First	11.67	11.67

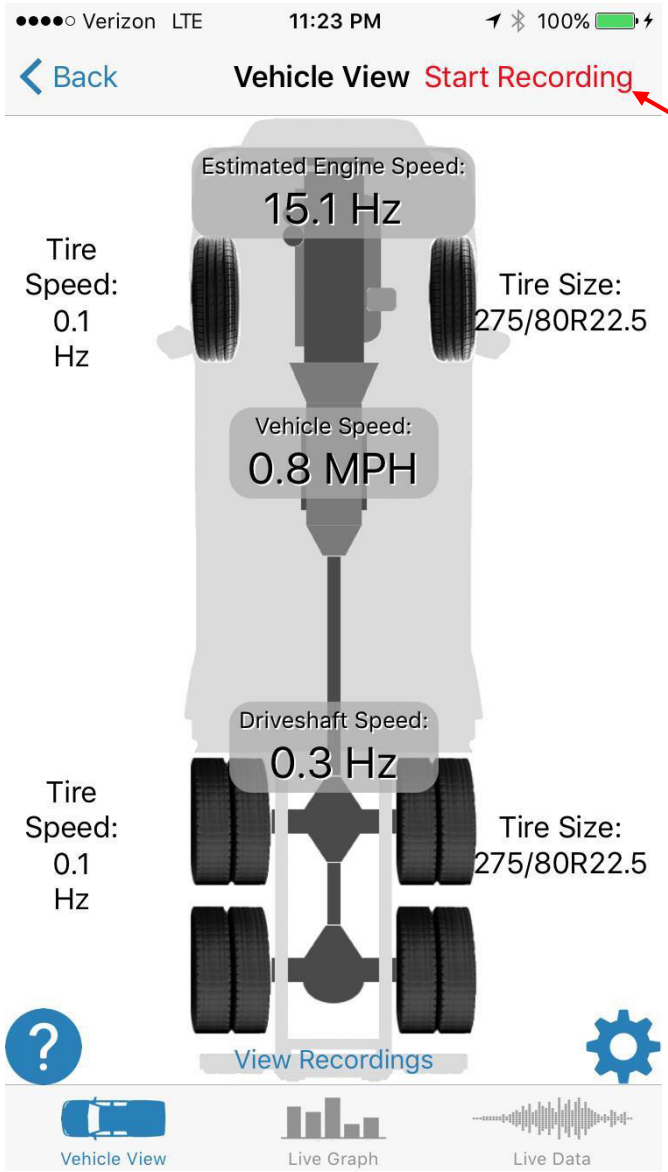
iPhone App



Type in Tire Sizes and Hit “Start” and Save File as Last six of Vin.



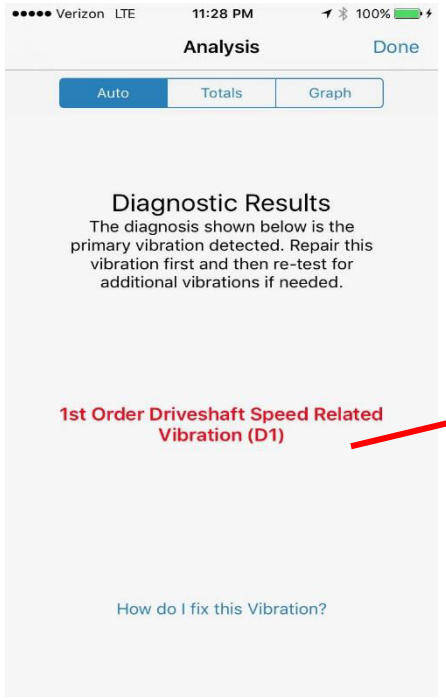
Type In

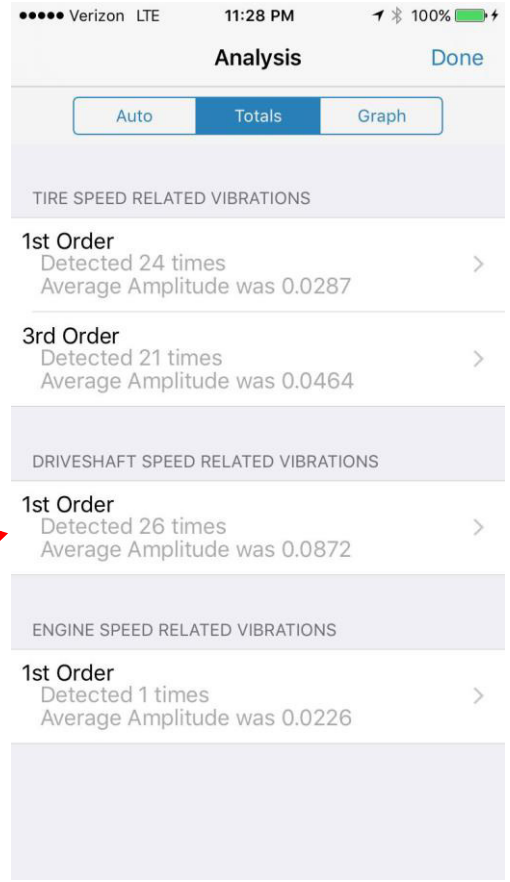


Start Recording

iPhone App Analysis

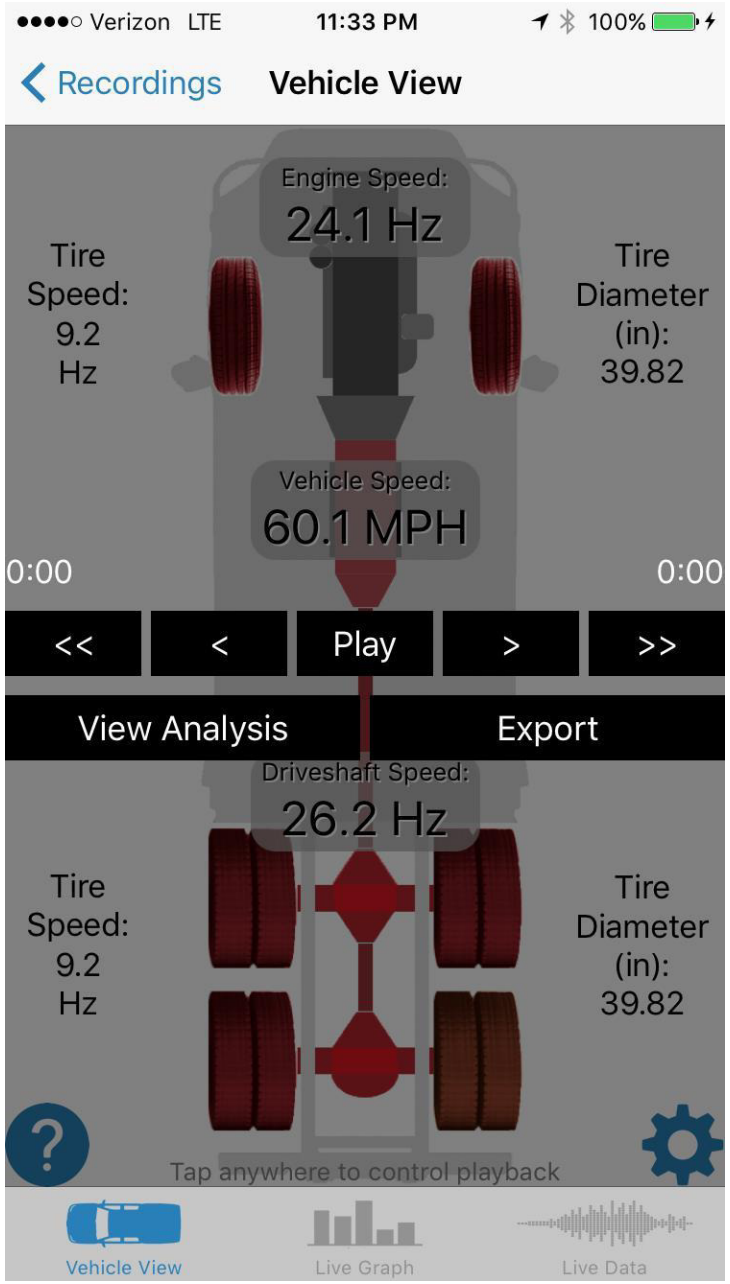
Place iPhone on solid surface. App will identify the primary vibration source under “Auto’. Identify vibration and average amplitude. Compare reading to chart



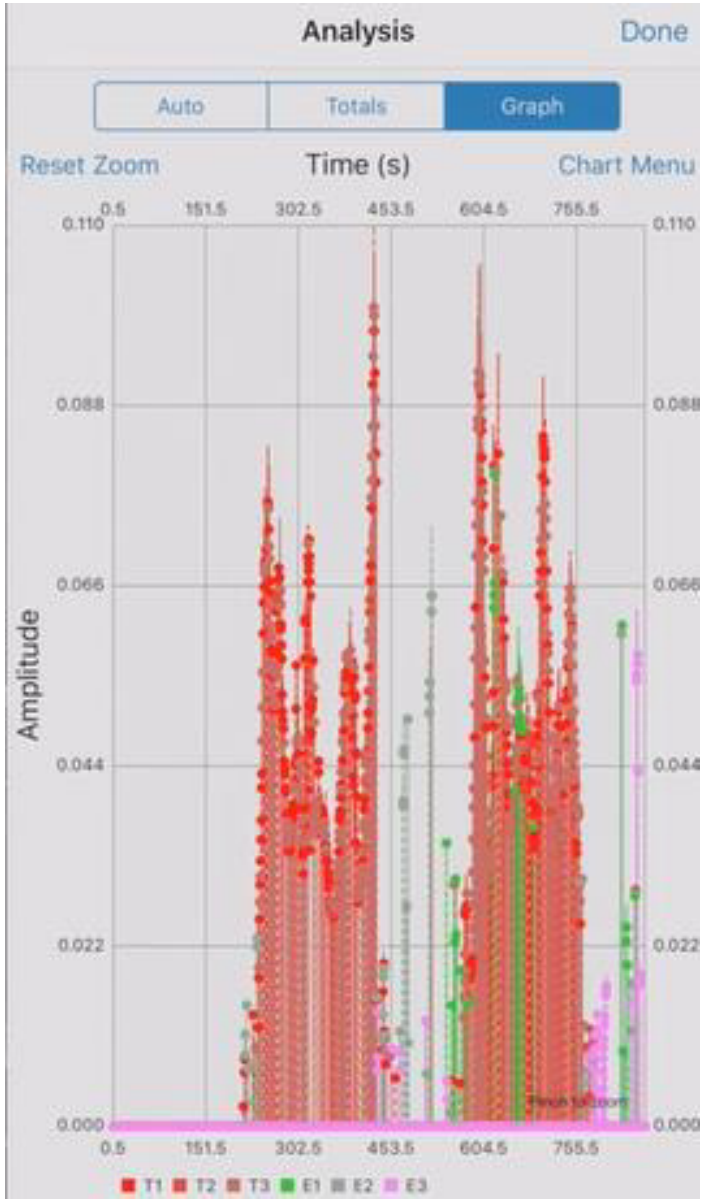


Export Analysis to Email

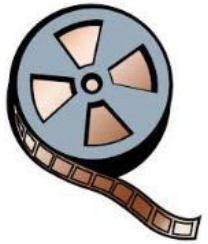
- Go to App home page and click “recordings” and select saved recording.
- Tap screen to give show options and click “Export” and send via email.
- Or, click view analysis and capture image (click off and home button at the same time).

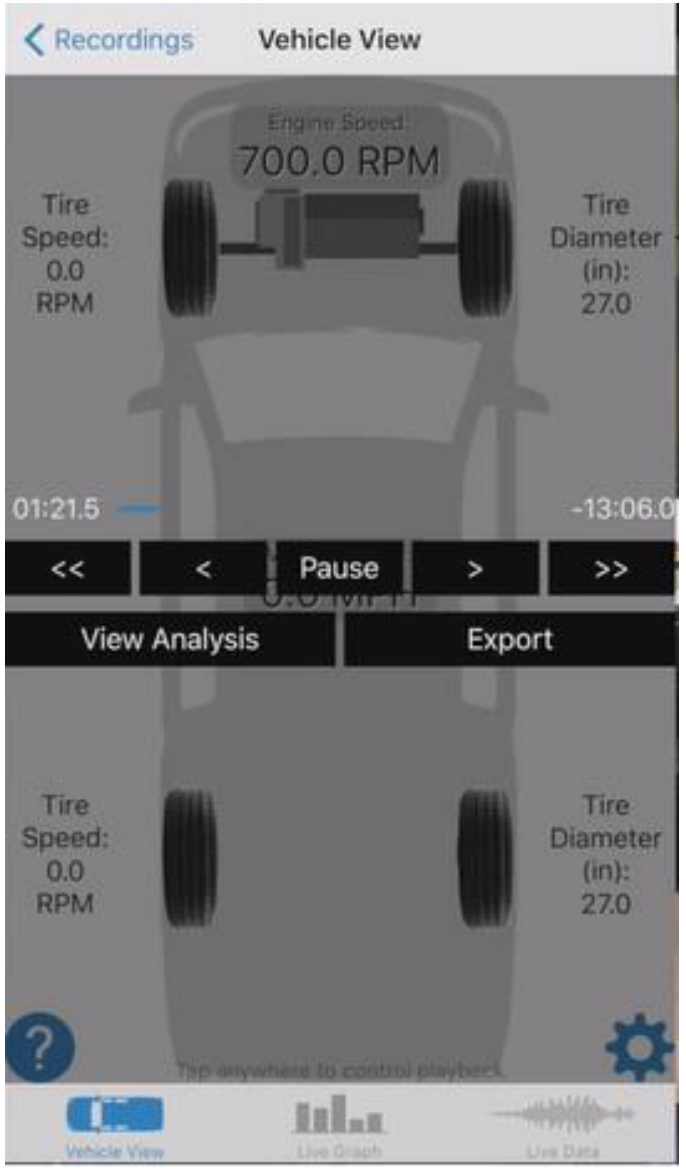


Additional Functions of IPhone APP



- Has a view that graphs the “Y” axis (up & down) allowing you to view the amplitude level versus time.
- Color coded by frequency at bottom of graph





- You can view the recording in their entirety
- Simply tap the screen anywhere
- There are pause and arrow buttons to move you through playback
- Single arrow buttons move you through at 1 second. Double arrow moves you at 5 seconds.
- You can play back any of the views at the bottom of the screen
- Allows you to export a CSV file.

CSV File Sharing

The CSV file was not intended to be opened or analyzed in a spreadsheet, it contains information that is used internally by the program to perform diagnostics. Much of it may not make sense to anyone else.

You can share the recordings with other users of the NVH app by emailing them the recording.

On the phone with the recording:
1. Select “Recordings" from upper right corner of the main screen
2. Touch and hold your finger on the recording name you with to email
3. Select email from the menu and send the email to another user.

On the phone receiving the recording:
1. Open the email with the recording, but do not open the recording file
2. Touch and hold your finger on the attached recording
3. Select “Copy to NVH” from the menu
4. Click “Recordings” from the screen and scroll to the bottom of the list to find the imported recording
5. Open the recording and use the play back controls to view the recording

Email Confirmation & Overview

Message | 2016 Mercedes-Benz Gle Class 2017-12-15 105811.csv (66 KB)

Recording Overview

Recording Name: 2016 Mercedes-Benz Gle Class
Recording Date: 2017-12-15 10:58:11

Vehicle Information

Manufacturer: Mercedes-Benz
Year: 2016
Model: GLE Class
Powertrain: FWD
Number of cylinders: 4
Tire Diameter: 29.04
Axle Gear Ratio: 3.27
Transmission Gear Ratio - 1st Gear: 4.377
Transmission Gear Ratio - 2nd Gear: 2.859
Transmission Gear Ratio - 3rd Gear: 1.921
Transmission Gear Ratio - 4th Gear: 1.368
Transmission Gear Ratio - 5th Gear: 1.0
Transmission Gear Ratio - 6th Gear: 0.82
Transmission Gear Ratio - 7th Gear: 0.728

Sample Exported CSV File

- File can be used to call out specific area of issue

recName	recDate	Manufactur	Year	Model	powertrair	numCylind	tireDiamet	frontTireD	axleGearR	frontAxleG	rearAxleGe	tCaseGear	transGearF	transGearF	transGearF	transGearF	transGearF	transGearF
2016 Merc	########	mercedes-b	2016	GLE Class	FWD	4	29.04	29.04	-1	3.27	-1	1	2.859	1.921	1.368	1	0.82	0.728
Time (s)	Engine RPI	Speed (m/s)	Tire Hz	Front Tire	Driveshaft	Freq1 (Hz)	Freq2 (Hz)	Freq3 (Hz)	AvgMag1	AvgMag2	AvgMag3	xMag1	yMag1	zMag1	xMag2	yMag2	zMag2	xMag3
10	2178.038	35.349998	15.24878	15.24878	2991.811	12.65625	14.0625	15.46875	0.056902	0.051874	0.050117	0.001508	0.002473	0.124691	0.013095	0.010768	0.064432	0.038719
10.5	2194.058	35.610001	15.24878	15.24878	2991.811	12.65625	14.0625	74.53125	0.056179	0.052296	0.051499	0.010024	0.002197	0.009304	0.002019	0.013474	0.078558	0.030884
11	2194.058	35.610001	15.36094	15.36094	3013.816	12.65625	15.46875	14.0625	0.056279	0.054201	0.049296	0.017816	0.006268	0.00733	0.010613	0.036771	0.052821	0.001058
11.5	2216.239	35.970001	15.36094	15.36094	3013.816	15.46875	14.0625	0	0.057316	0.050092	0	0.045393	0.01149	0.059681	0.014739	0.007646	0.023763	0
12	2216.239	35.970001	15.51623	15.51623	3044.284	15.46875	12.65625	14.0625	0.058138	0.057763	0.050631	0.012283	0.002328	0.02103	0.005016	0.004723	0.042942	0.00662
12.5	2222.4	36.07	15.51623	15.51623	3044.284	15.46875	8.4375	32.34375	0.059168	0.056483	0.00636	0.022433	0.004742	0.006673	0.003152	0.003048	0.010376	0.000559
13	2222.4	36.07	15.55937	15.55937	3052.748	12.375	11	0	0.056364	0.039784	0	0.004342	0.000352	0.013935	0.003395	0.00039	0.010368	0
13.5	2232.258	36.23	15.55937	15.55937	3052.748	12.65625	16.875	0	0.030347	0.014453	0	0.003477	0.000962	0.013789	0.005955	0.011258	0.001453	0
14	2232.258	36.23	15.62838	15.62838	3066.289	15.46875	14.0625	12.65625	0.050159	0.029375	0.024417	0.01831	0.000842	0.008816	0.017934	0.004406	0.04537	0.016696
14.5	2238.42	36.330002	15.62838	15.62838	3066.289	15.46875	75.9375	32.34375	0.050174	0.027578	0.00759	0.024826	0.000124	0.004701	0.020725	0.002974	0.029317	0.008543
15	2238.42	36.330002	15.67152	15.67152	3074.753	16.875	32.34375	2.8125	0.011029	0.008014	0.005337	0.006203	0.016964	0.002579	0.001476	0.010983	0.001483	0.00088
15.5	2234.723	36.27	15.67152	15.67152	3074.753	15.46875	14.0625	8.4375	0.046751	0.026328	0.00628	0.024006	0.000843	0.007577	0.004658	0.004007	0.011877	0.000601
16	2234.723	36.27	15.64564	15.64564	3069.674	72.875	13.75	17.875	0.04745	0.026786	0.006974	0.008999	0.009261	0.034867	0.013232	0.000446	0.010968	0.013733
16.5	2218.087	36	15.64564	15.64564	3069.674	15.46875	14.0625	1.40625	0.048163	0.025137	0.013185	0.030633	0.005157	0.003398	0.007785	0.003628	0.026462	0.001093
17	2218.087	36	15.52917	15.52917	3046.823	15.8125	14.375	1.4375	0.047627	0.024762	0.015932	0.020784	0.029492	0.068142	0.004633	0.004223	0.012988	0.001056
17.5	2202.684	35.75	15.52917	15.52917	3046.823	72.875	13.75	1.375	0.046495	0.026613	0.016562	0.004249	0.013786	0.04408	0.013279	0.015985	0.032415	0.0021
18	2202.684	35.75	15.42133	15.42133	3025.665	15.125	13.75	12.375	0.042462	0.028973	0.021294	0.018056	0.002204	0.00387	0.001343	0.009631	0.047588	0.002606
18.5	2194.058	35.610001	15.42133	15.42133	3025.665	74.53125	14.0625	12.65625	0.038652	0.029576	0.022553	0.001751	0.000571	0.018344	0.005881	0.006319	0.01695	0.006375

PDF File

NVH Diagnostic Report

Report Date	Record Name	Record Date	Record Length
November 14, 2018	dutch star JB3378#1	2018-11-13 15:08:29	05:25.0

Vehicle Data:

- Manufacturer: Unlisted Vehicle
- Year: Unlisted Vehicle
- Model: Unlisted Vehicle
- Powertrain: Class 4 - 8 Truck MD/HD
- Number of Cylinders: 6
- Front Tire Diameter: 42.62
- Rear Tire Diameter: 42.34
- Rear Axle Gear Ratio: 4.78
- Transmission Speeds: 6

Relevant Settings:

- Amplitude Threshold: 0.01g
- 3rd Order Tire Vibration analysis disabled

Diagnostic Results

The diagnosis shown below is the primary vibration detected. Repair this vibration first and then re-test for additional vibrations if needed.

(T2) 2nd Order Rear Tire speed related vibration

Definition: Second order tire speed related vibrations cause two shakes or disturbances for each revolution of the tire. These vibrations are usually caused by something spinning the same speed as the tire that is out-of-round. There are over 77 conditions that can cause a tire speed related vibration.

Totals

Rear Tire Speed Related Vibrations

Order	Times Detected	Average Amplitude (g)
1st	12	0.01
2nd	189	0.01
3rd	20	0.03

Front Tire Speed Related Vibrations

Order	Times Detected	Average Amplitude (g)
1st	12	0.01
2nd	150	0.01
3rd	18	0.03

Driveshaft Speed Related Vibrations

Order	Times Detected	Average Amplitude (g)
1st	11	0.02
3rd	9	0.03

Engine Speed Related Vibrations

Order	Times Detected	Average Amplitude (g)
3rd	7	0.02

Vibration Breakdown By Vehicle Speed

The NVH app takes samples of the vibrations on your vehicle twice per second.

- The counts shown below indicate the number of times each type of vibration was detected in that particular vehicle speed range.
- The maximum counts possible column shows the total amount of counts that were possible for that vehicle speed range. This is related to how long was spent driving in that speed range.
- The Percentage column shows the percentage of time the vibration was detected at that vehicle speed range

Rear Tire Speed Related Vibration Breakdown

1st Order Rear Tire Speed Related Vibration Breakdown

Vehicle Speed	Count	Count (Time) Spent in Range	Percentage	Average Amplitude (g)
5-9 MPH	3	6 (00:03.0)	50.00%	0.01
10-14 MPH	6	6 (00:03.0)	100.00%	0.01
15-19 MPH	3	10 (00:05.0)	30.00%	0.01

2nd Order Rear Tire Speed Related Vibration Breakdown

Vehicle Speed	Count	Count (Time) Spent in Range	Percentage	Average Amplitude (g)
35-39 MPH	1	10 (00:05.0)	10.00%	0.03
40-44 MPH	6	12 (00:06.0)	50.00%	0.02
45-49 MPH	2	10 (00:05.0)	20.00%	0.01
55-59 MPH	9	189 (01:34.5)	4.76%	0.01
60-64 MPH	139	254 (02:07.0)	54.72%	0.01
65-69 MPH	32	48 (00:24.0)	66.67%	0.01

3rd Order Rear Tire Speed Related Vibration Breakdown

Vehicle Speed	Count	Count (Time) Spent in Range	Percentage	Average Amplitude (g)
25-29 MPH	4	10 (00:05.0)	40.00%	0.02
30-34 MPH	4	4 (00:02.0)	100.00%	0.03
35-39 MPH	2	10 (00:05.0)	20.00%	0.04
40-44 MPH	10	12 (00:06.0)	83.33%	0.03

Front Tire Speed Related Vibration Breakdown

1st Order Front Tire Speed Related Vibration Breakdown

Vehicle Speed	Count	Count (Time) Spent in Range	Percentage	Average Amplitude (g)
5-9 MPH	3	6 (00:03.0)	50.00%	0.01
10-14 MPH	6	6 (00:03.0)	100.00%	0.01
15-19 MPH	3	10 (00:05.0)	30.00%	0.01

2nd Order Front Tire Speed Related Vibration Breakdown

Vehicle Speed	Count	Count (Time) Spent in Range	Percentage	Average Amplitude (g)
35-39 MPH	1	10 (00:05.0)	10.00%	0.03
40-44 MPH	4	12 (00:06.0)	33.33%	0.02
45-49 MPH	2	10 (00:05.0)	20.00%	0.01
55-59 MPH	9	189 (01:34.5)	4.76%	0.01
60-64 MPH	102	254 (02:07.0)	40.16%	0.01
65-69 MPH	32	48 (00:24.0)	66.67%	0.01

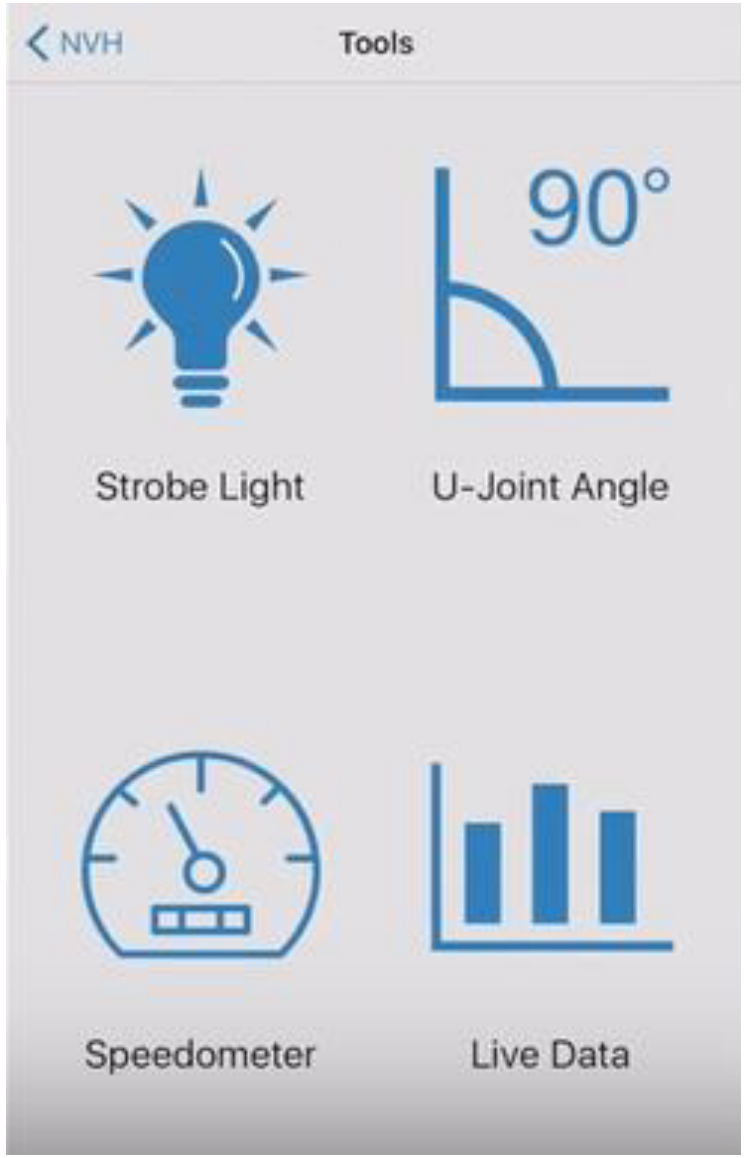
3rd Order Front Tire Speed Related Vibration Breakdown

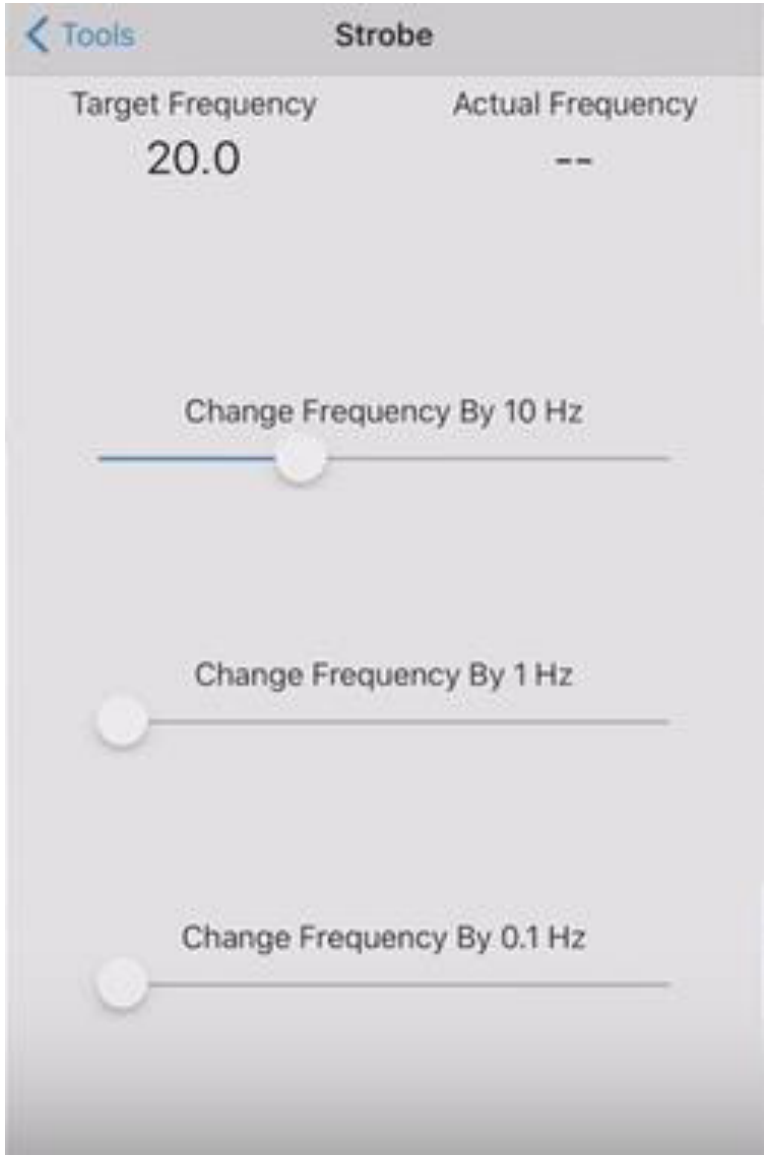
Vehicle Speed	Count	Count (Time) Spent in Range	Percentage	Average Amplitude (g)
25-29 MPH	4	10 (00:05.0)	40.00%	0.02
30-34 MPH	4	4 (00:02.0)	100.00%	0.03
40-44 MPH	10	12 (00:06.0)	83.33%	0.03

iPhone App

- Perform related checks corresponding to classification and order to fix issue(s)
- Take a second recording (same route) and save as last six of VIN.
- Export second recording for proof that issue has been resolved.

Additional Functions of IPhone APP





- **Strobe Light** function to determine rotational speed of components not identified by the NVH app
- **U-Joint Angle** measuring device
- **Speedometer** Accuracy tool
- **Live Data** of three axis sensors measuring frequency and amplitude levels. Top 5 amplitudes and frequency displayed

Source Analysis: Tires/Wheel End

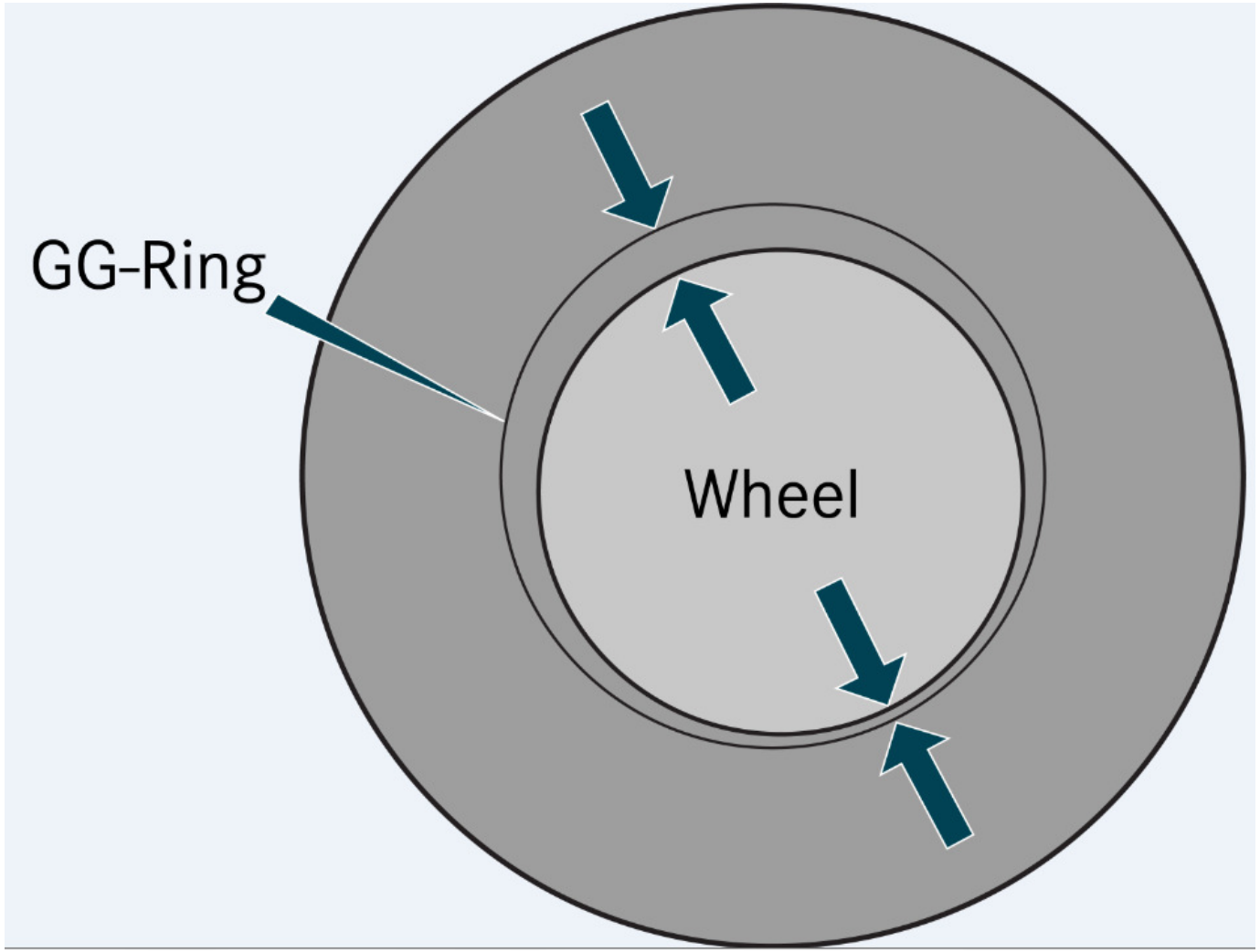
- **Tire and Wheel End related vibrations Tire 1st order**
- Condition of tires, flat spots, dry rot, chunks missing etc.
- Tire mounted on wheel incorrectly “GG Ring”, Guide rib, or Mold Line measurement should not exceed 2/32” in 4 spots
- Tire run out radial and lateral
- Wheel mounted on hub piloted assemblies incorrectly
- Check wheels, hubs, drums, rotors if necessary
- Balance wheel/tire assemblies, drum or rotors
- Stiff spots in tire sidewall (radial force variation)

First Order Tire Speed Related Vibrations

Usually caused by something rotating the same speed as the tire that is out-of-round or out-of-balance

Tire Mounting GG Ring/Guide Rib/Mold Line

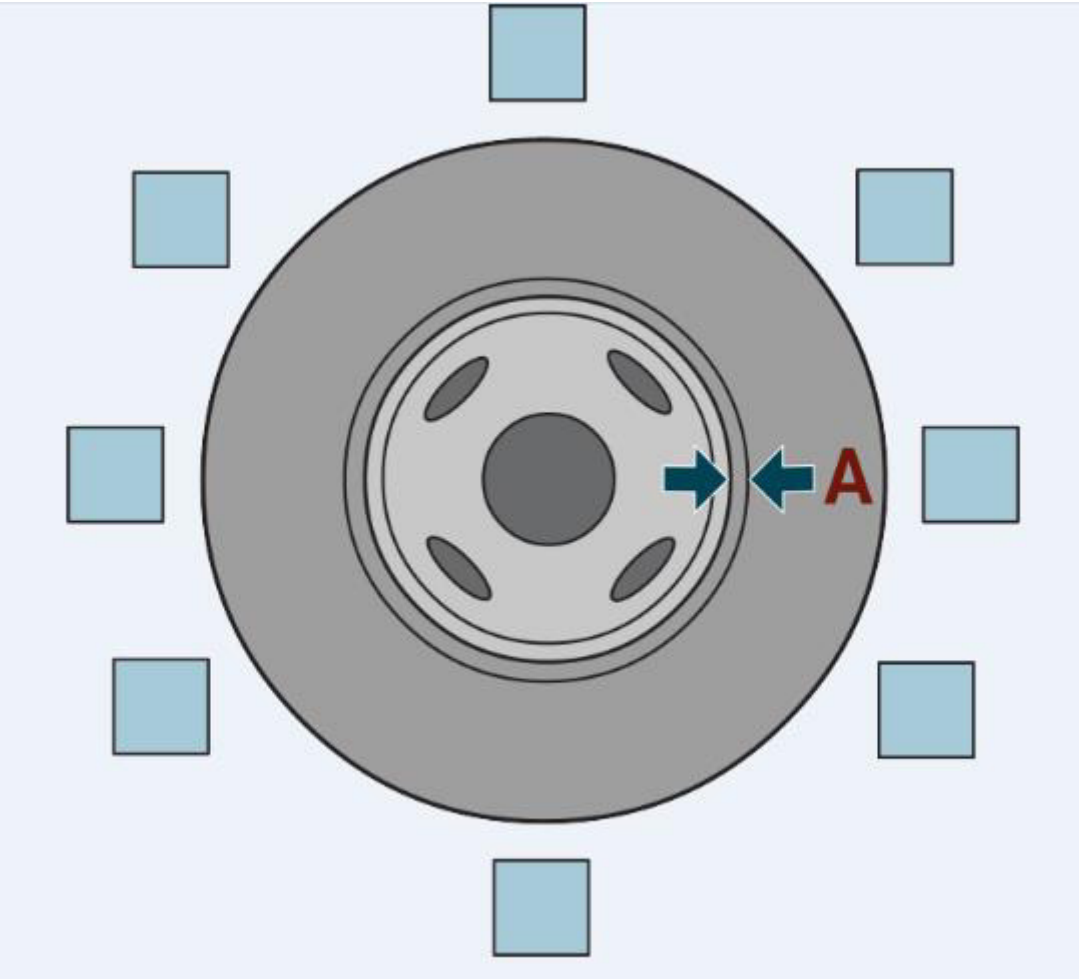
- The GG Ring, Guide Rib or Mold Line is the raise rib close to the bead.



Tire Mounting GG Ring/Guide Rib/Mold Line

- The GG Ring, Guide Rib or Mold Line is the raise rib close to the bead.

GG Ring Measurement



Tire on Wheel Mounting Record

Clock Position		A	Inspector
12:00			Date
1:30			
3:00			
4:30			
6:00			
7:30			
9:00			
10:30			

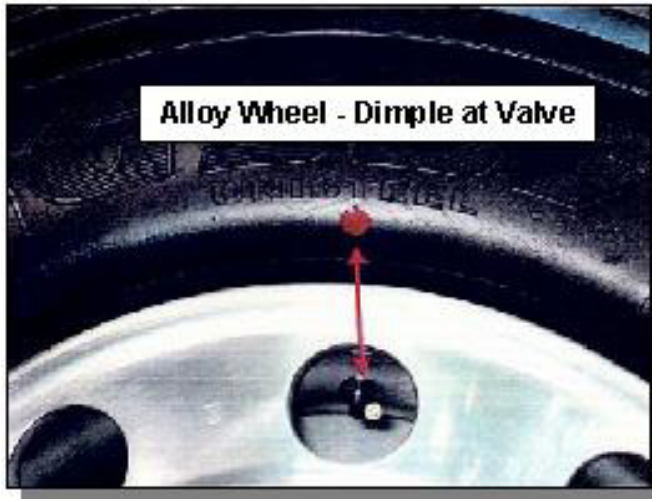
Tire Mounting

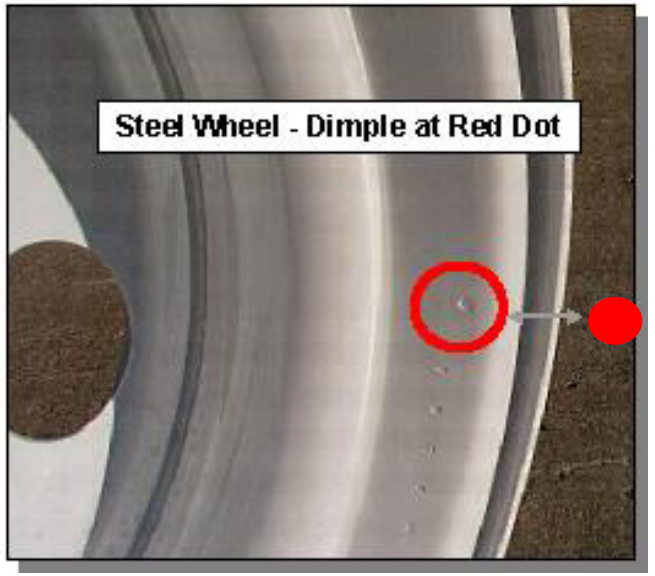
- Many Goodyear steer tires are marked with a **red dot** on the side wall which indicates the tires highest point of radial RFV or runout.

- To minimize assembly run-out:

- **Steel Wheels**
  Align the **red dot** (high point) with the dimple on the rim (low point)

- **Alloy Wheels**
  Align the red dot with the valve stem





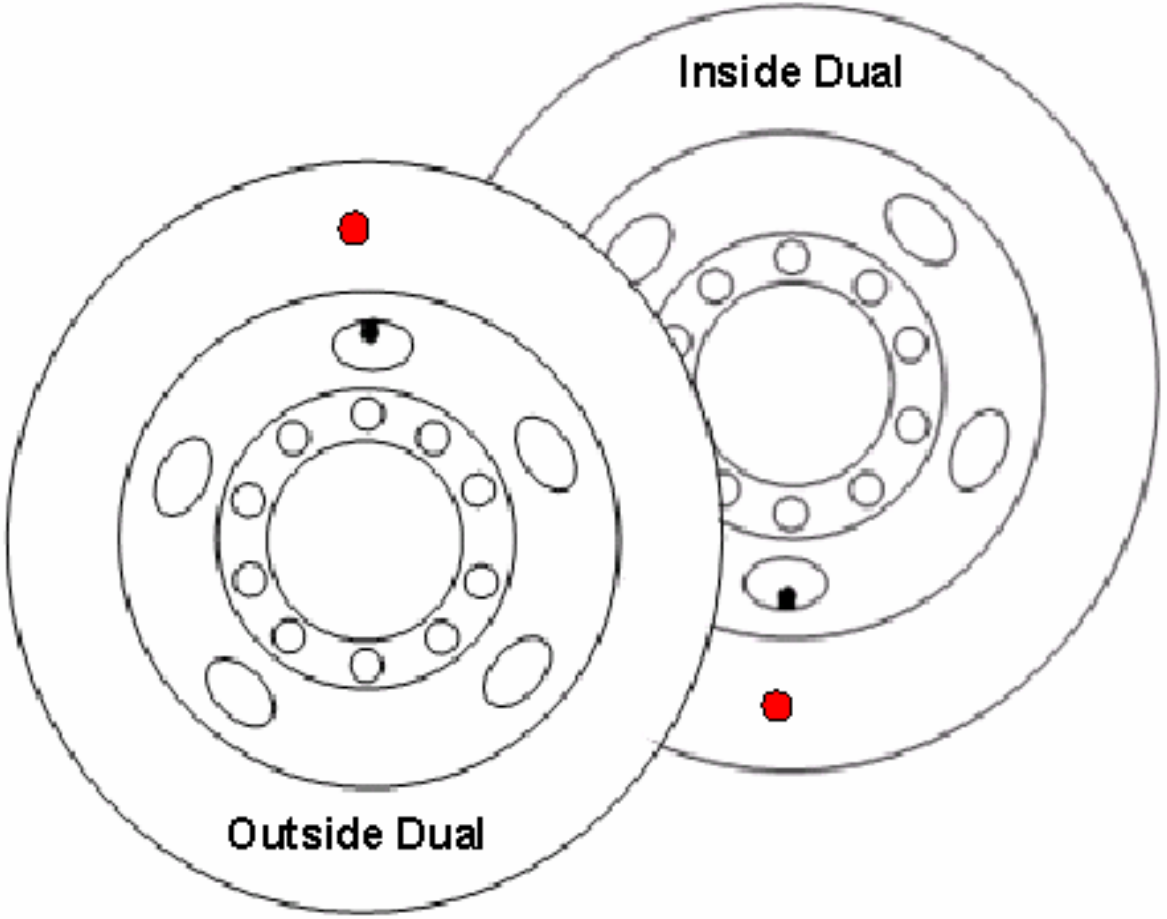
Tire Mounting Rear

- Most truck drive (traction) tires are not **red dot** marked. However most Motorhomes use Rib tires in all positions which are generally marked.

- When installing **red dot** marked tires on drive axles, place **red dots** opposite of each other.

- Clock red dots at 12:00 o' clock and 6:00 o' clock position

- Maintain Valve stem access

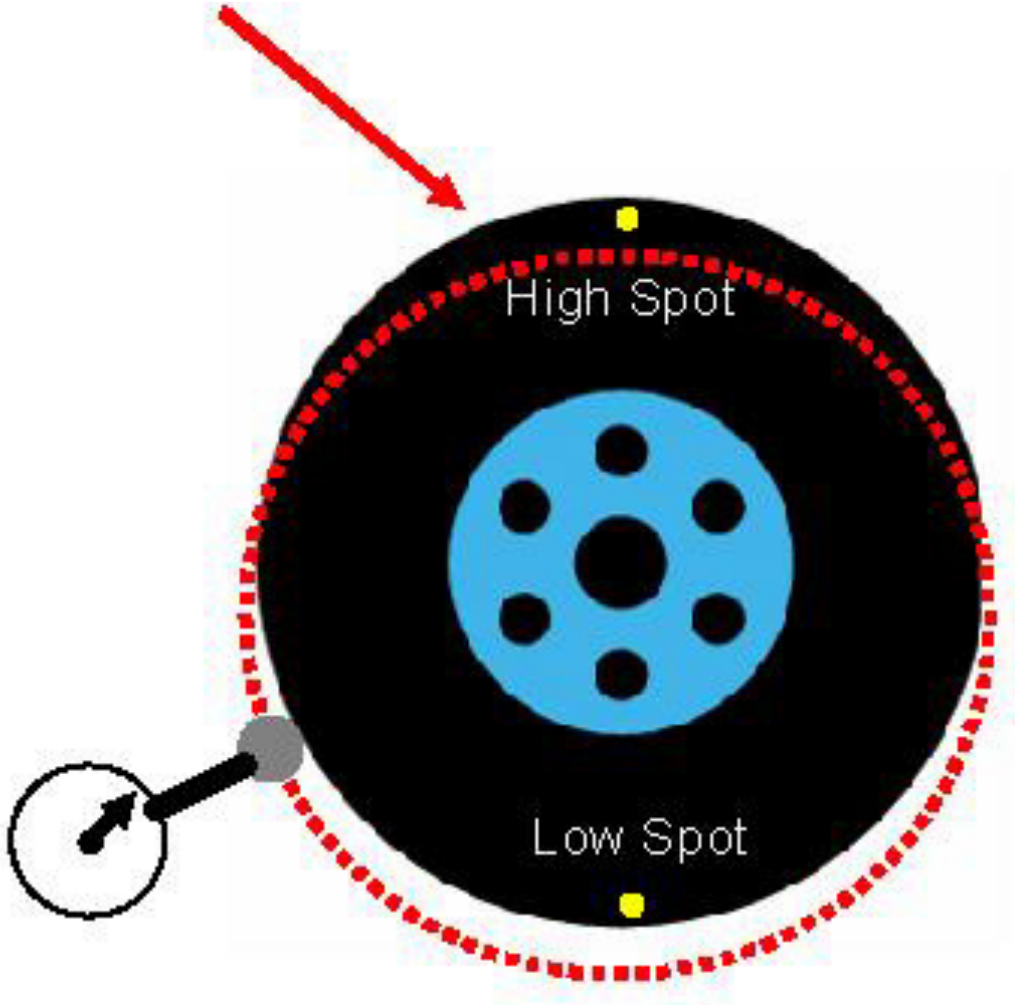


Wheel End Run-outs

- Radial Run-out is a deviation from a perfect circle.

- The steer axle is usually more sensitive than the drive axle

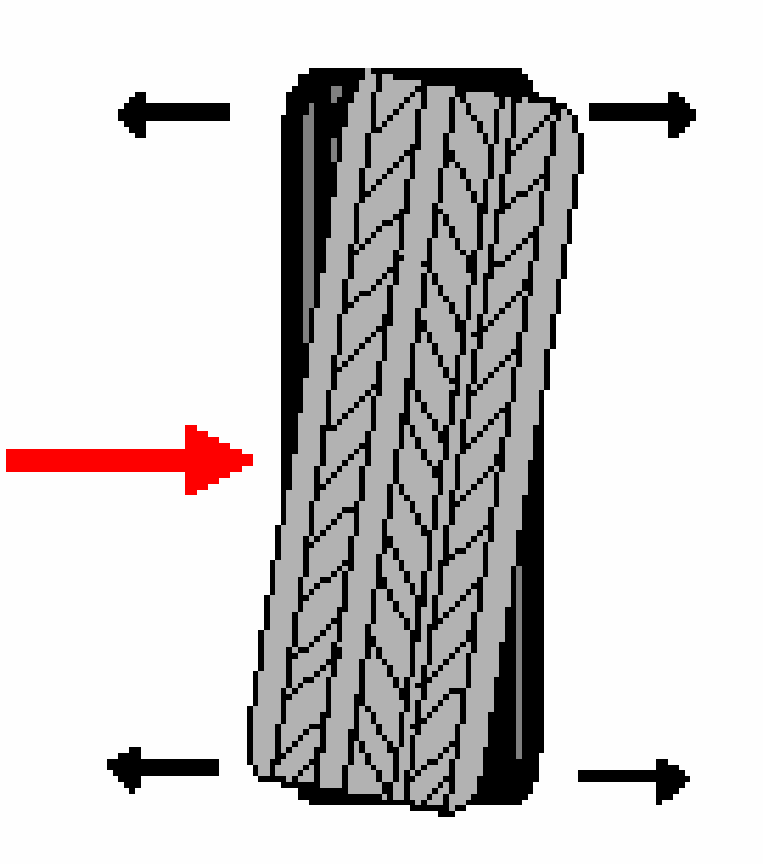
- Radial Run-out taken at the center rib of tire **.060”** Total Run-out is maximum allowed specification



Wheel End Run-outs

- Lateral run-out Is the side to side movement

- Lateral taken close to the “GG” Ring **.060”** is the maximum allowed specification



Measuring Wheel End Run-outs

- Use an approved dial indicator

Wheel Run-Out

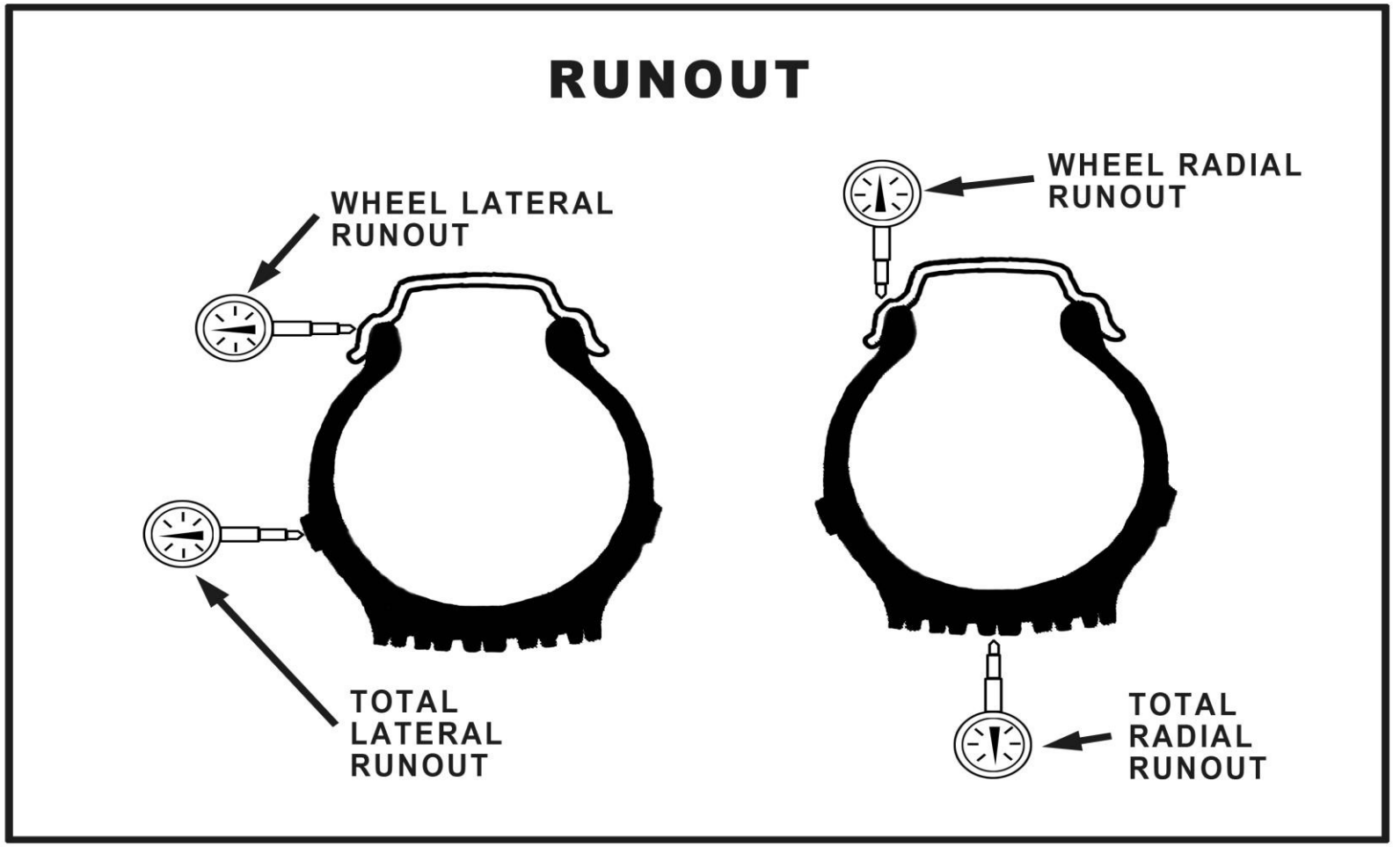
- Rim measurement readings:

Aluminum

Lateral .030” max
Radial .030” max

Steel

Radial .050” max
Lateral .050” max



Tire and Wheel End/Brake Drum & Types

- Brake Drum measurement readings
  Lateral .045”
  Radial taken inside of Drum .020”

- Note: Brake run-outs typically do not cause a vibration until the brake pedal is depressed.

- Look for missing weights

Machined-to-Balance

Welded balance weight

Brake Drum Storage

➢ How to Properly Store Brake Drums

Correct:

Correct stacking of brake drums will ensure the distribution of the weight onto the side walls of the drum.

Incorrect:

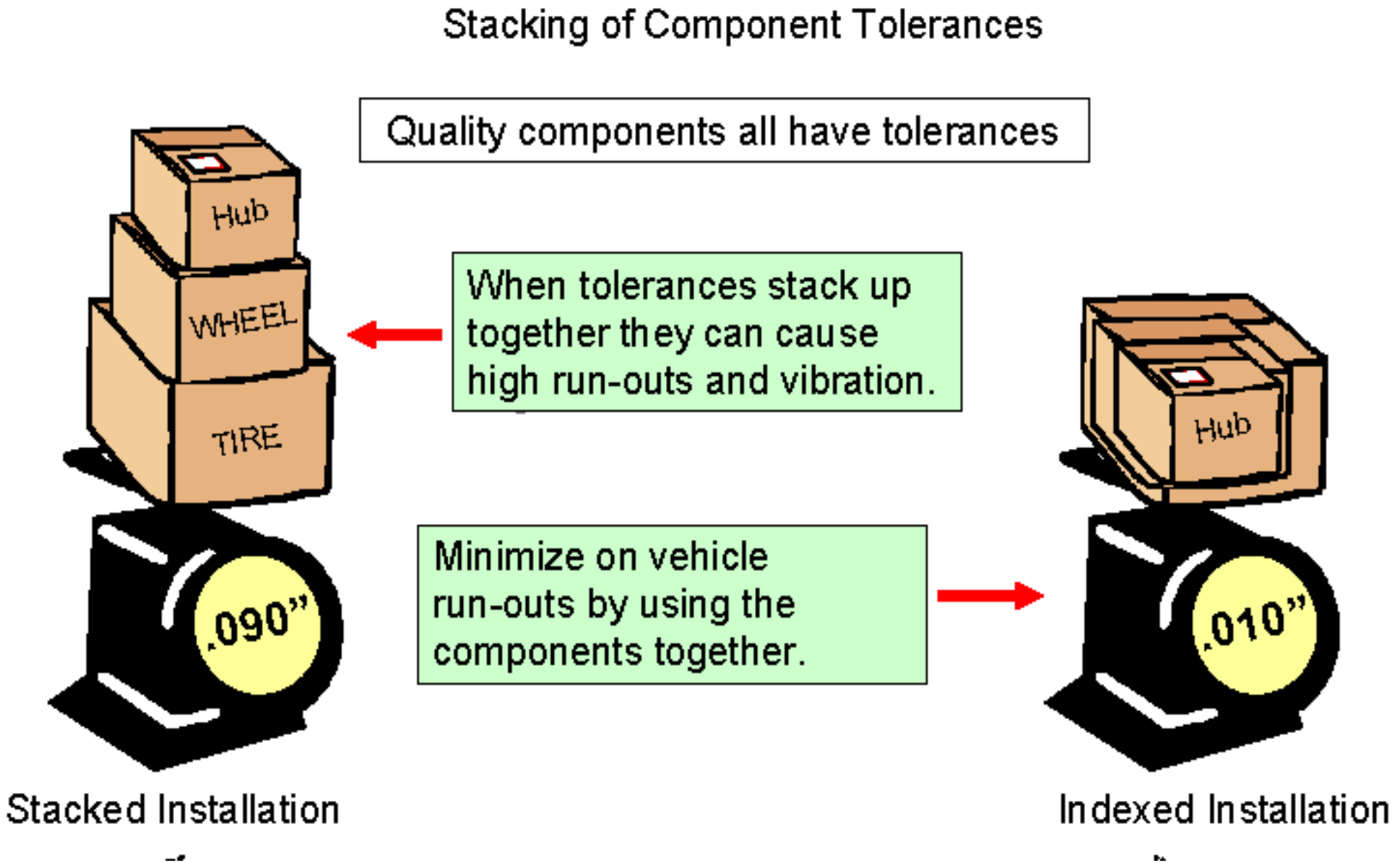
Incorrect stacking such as "nesting", "stacking" or the "book end" styles illustrated above, will cause out-of-round conditions. Drums stored in this manner normally require additional turning, which shortens their useful life.

Tire and Wheel End / Hub

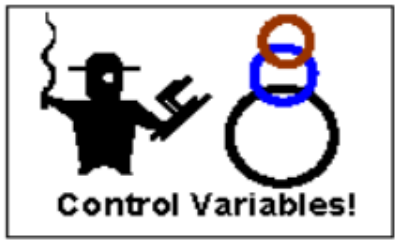
- Hubs:
  Lateral taken at the face of the hub .015”
  Radial taken near the hub pilots .015”

- Make sure piloted hubs are installed correctly

Wheel End/Component Tolerance Stack-up

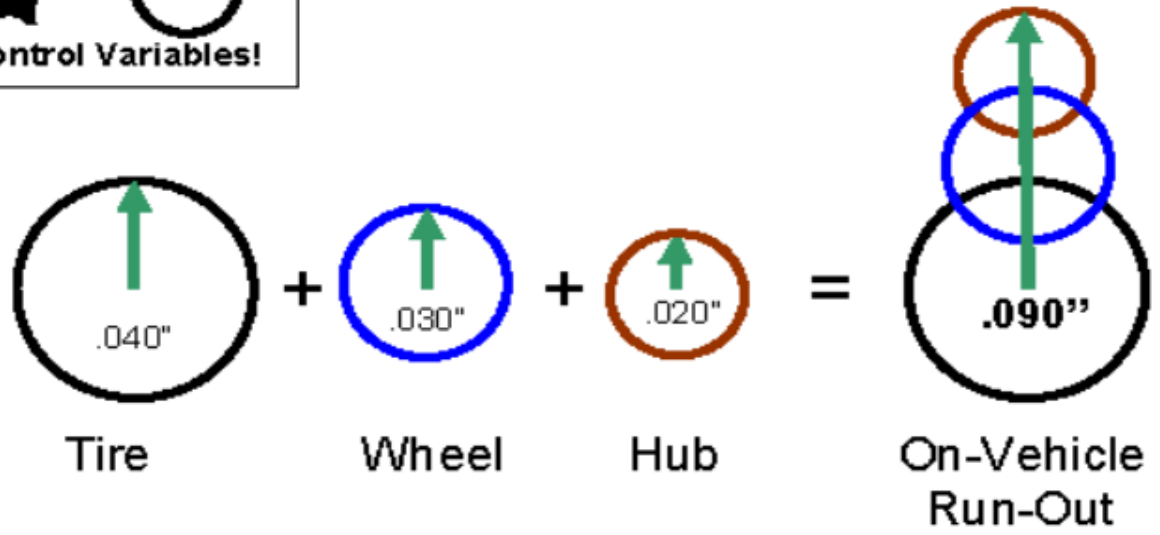


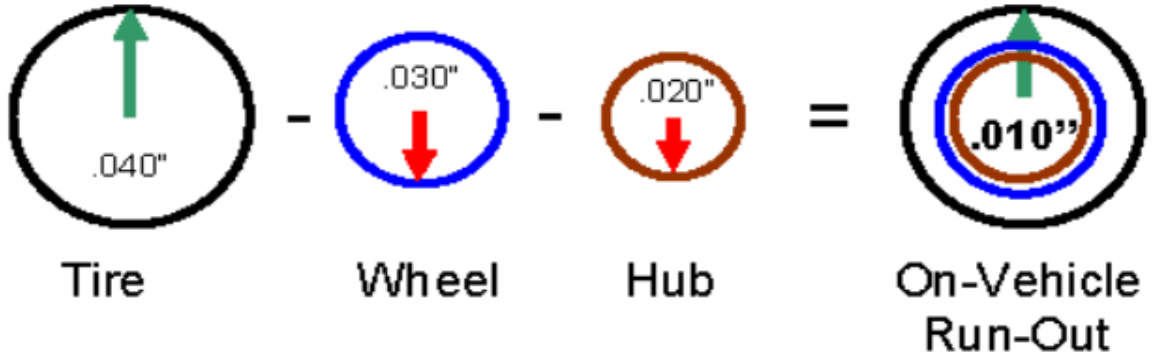
Wheel End Components Tolerance Stack-Up



Stacking of Component Tolerances

Another View – Component Run-outs



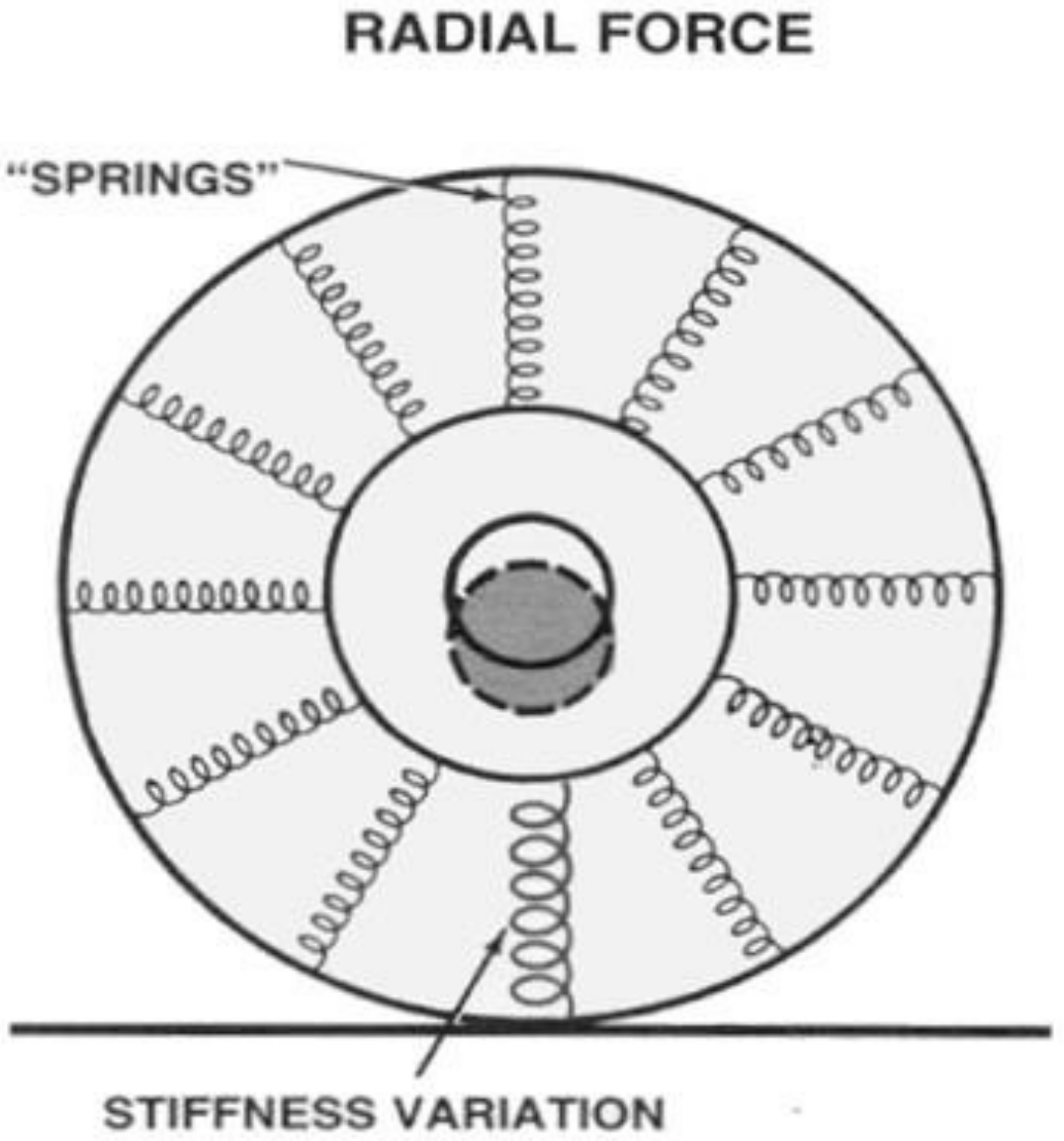


Tire/Wheel End 2nd Order

- **Tire 2nd order**
- Tire, wheel, drum, rotor or hub out of round
- Balance will not cause Tire 2nd order issues.
- Radial Force Variation (RFV) which is soft or stiff spots in tire which can not support the load efficiently.
- RFV can be measured **(See SB 32-31)** entitled Rough Ride Diagnosis for procedure to measure RFV.
- RFV can also be measure by a machine such as the Hunter GSP9700 Road Force Balancer which is used to balance and load the tire.

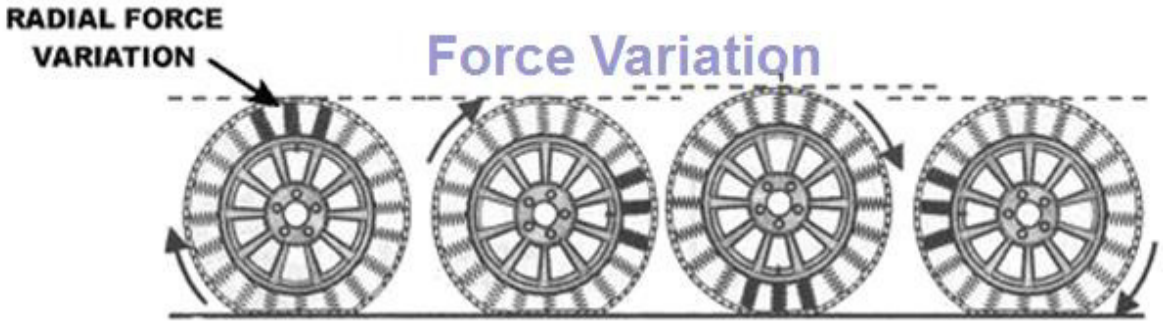
Hunter GSP9700

Wheel End 2nd Order Radial Force Variations

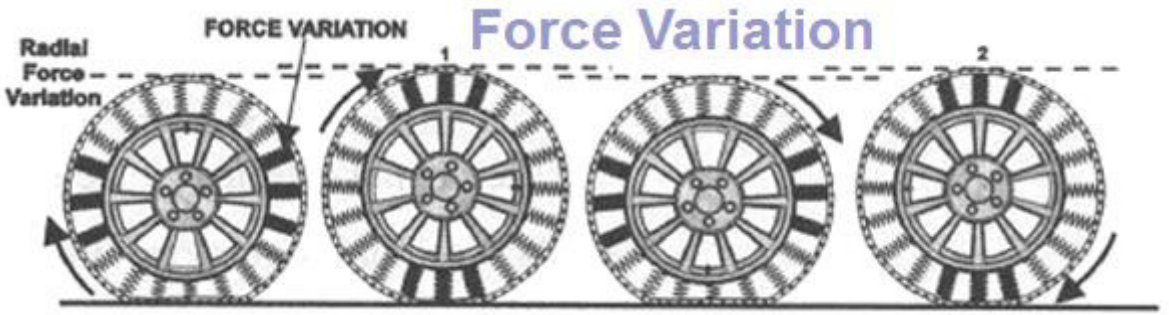


Wheel End 2nd Order Radial Force Variations

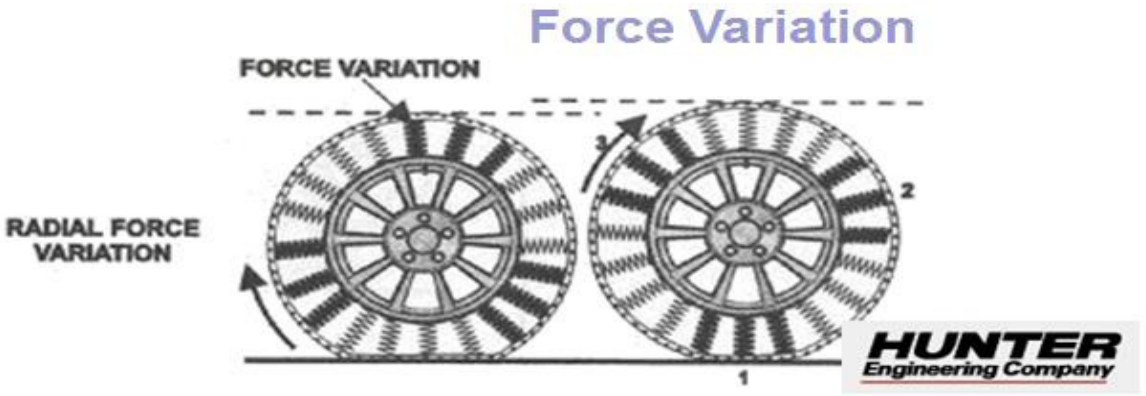
1st Order



2nd Order



3rd Order



Tire/Wheel End 2nd Order

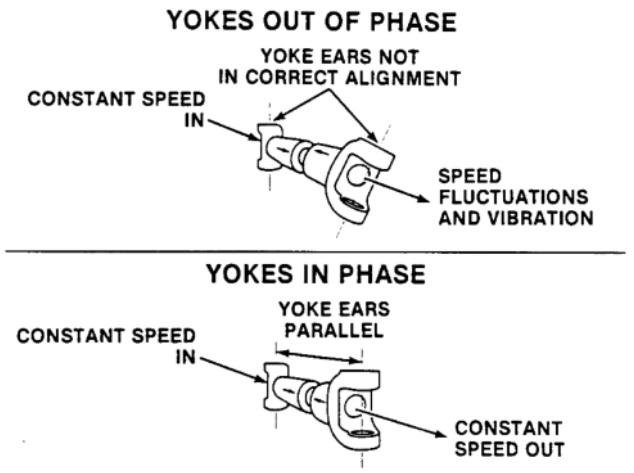
Frame Beaming

- **Frame Beaming** is a condition usually appearing in extremely long wheel bases where the frame is actually flexing.
- Frame Beaming displays as a 1st order wheel end issue, but **does not increase HZ with vehicle speed** like a true wheel end issue. The HZ can also slightly change from bobtail mode when a loaded trailer is added.
- If balance or runout does not resolve your issue you will need to contact Service Engineering. Possible solutions may include different cab shocks, different durometer cab mounts, or adding ping tanks.
- Adding frame inserts is very costly and often does not resolve the issue.

Source Analysis/ Driveline 1st Order

➢ Driveline 1st Order

- ✓ Check driveline run outs (shaft, yoke, flange, parking brake)
- ✓ Check “U” joints, slip yokes, & carrier bearings. for excessive play.
- ✓ Check yoke or companion flange nuts for looseness
- ✓ Check for drive line balance weights missing
- ✓ Check for mud or concrete build up
- ✓ Check for dents or twists
- ✓ Check for proper phasing (note some Western Star
- ✓ drive line assemblies are phased out 90 degrees)
- ✓ Check Driveline Balance
- ✓ Check Critical and ½ Critical Speeds

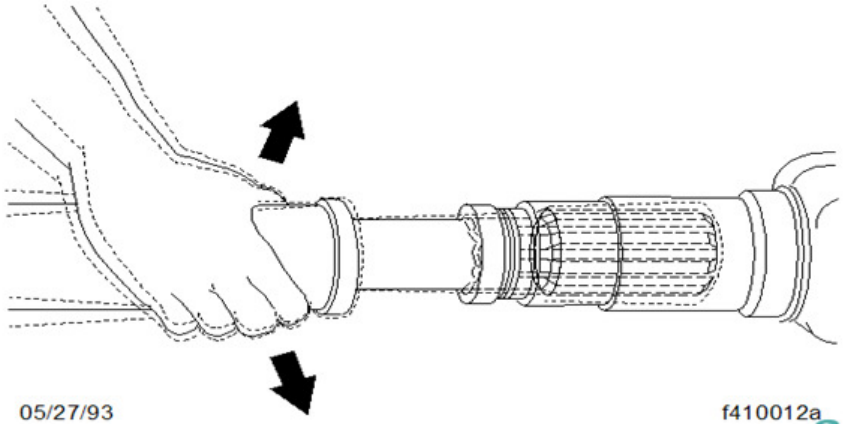


Driveline Specs

- Slip joint maximum radial looseness .007”
- “U” Joint maximum movement .006”
- Flange run out radial maximum .008”
- Flange run out axial maximum .005”
- Maximum driveshaft run out measured 3 inches from welds on either side .020”
- Maximum run out measured at center .025”
- Maximum run out at shaft near splines .015”

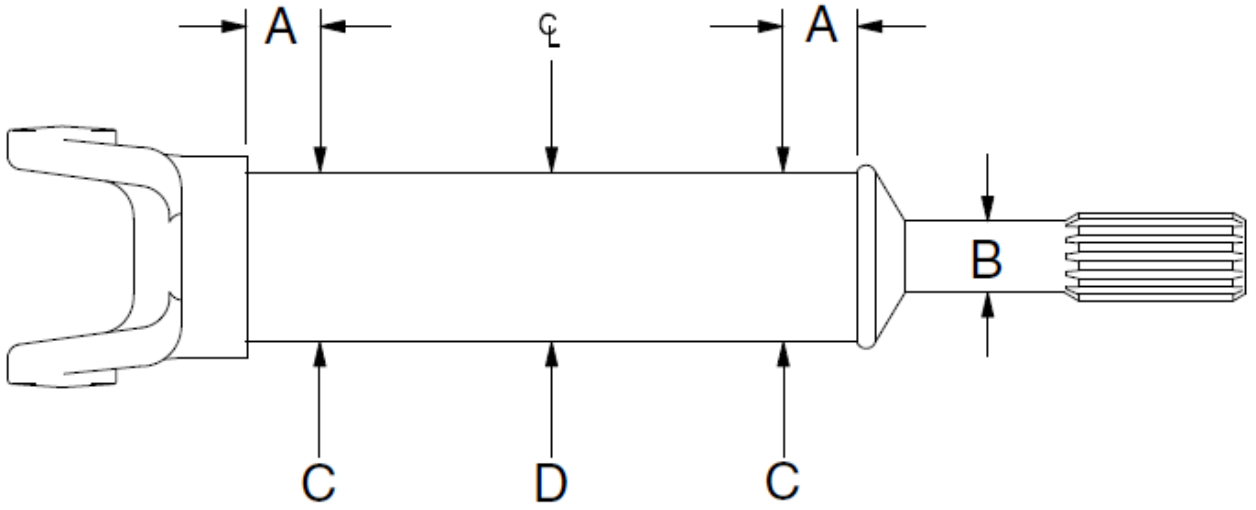
These specifications are for a driveshaft in a used condition

Figure 1, Checking for Slip-Joint Spline Wear



Drive Shaft Run Out

Dirveshaft Runout Specifications



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Measurment	New/Rebuilt	Used
A	3 inches (76 mm)	3 inch (76 mm
B	0.005 inch (0.127 mm)	0.015 inch (0.38 mm)
C	0.010 inch (0.2540 mm)	0.020 inch (0.51 mm)
D	0.015 inch (0.381 mm)	0.025 inch (0.635 mm)

Modules for Driveline Information

Module	Description
386	Driveshaft Main Rear Axle Input
388	Driveshaft interaxle
391	Driveshaft & Midship Brg. Forward #1

- **Note:** if the description of Part Pro does not contain the length. It can be determined by the last 3 digits. **Example A09-10277-530 = 53 inches, A09-30276-772 = 77 ½ inches.**
- The last digit represents ¼ inch. Therefore 1= ¼ 2=1/2 3=3/4.
- If the 4th digit is a 3 then the driveline is phased 90 degrees.

Driveline Information

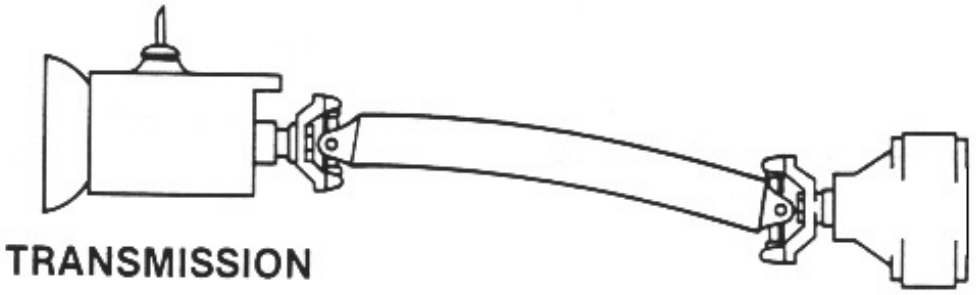
- **If the run outs and visual inspection look good there may be a balance issue.**

Note: EVA has an optional strobe attachment which can be used to verify an out of balance condition with the driveline.

Driveshaft Critical Speeds

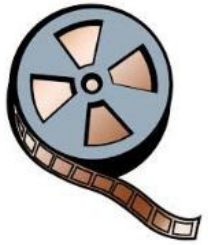
- ½ Critical Speed is important to check if runouts and balance are good.

- Critical speed of a driveshaft is the RPM at which the driveshaft will bend or whip



- Driveshaft's have a natural vibration or resonance at ½ critical speed.

- You never want the ½ critical speed of a driveshaft to occur within the 50 to 70 MPH range of a vehicle.

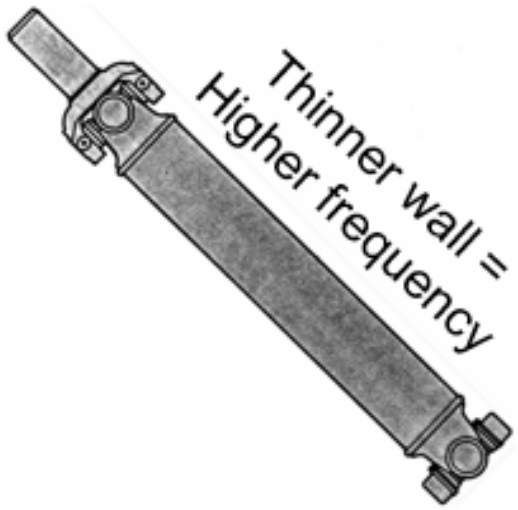


Driveshaft Critical Speed Calculation

Driveshaft Critical Speed Calculation
(Pin-Pin)

General Equation:

$$N_c = 30\pi\sqrt{\frac{EIg}{WL^3}}$$



where:
N_c= Revolutions per minute, rpm
E = Modulus of elasticity, psi
I = Area moment of inertia, in^4
g = Acceleration due to gravity, in/s^2
W = Total weight of shaft, lb
L = Shaft length between supports, in

Round Tubular Steel Shaft:

$$N_c = 4{,}705{,}000\,\frac{\sqrt{d_o^{\,2} + d_i^{\,2}}}{L^2}$$

where:
d_o= outside diameter, in
d_i = Inside diameter, in
L = Shaft length, in
note: for solid shaft, $d_i = 0$
(Hollow shaft gives higher N_c)

Driveshaft Critical & 1/2 Critical Speeds

- Use driveline calculator @ **www2.dana.com** to determine if driveline is operating at or near ½ critical speed.

Driveshaft 1/2 Critical Speeds Continued

DANA

The Expert **Driveshaft RPM Calculator**

The Expert | DanaMate.Com | Contact Us | NEW Search

Driveshaft RPM Calculator

Select Drive Shaft Type

- Style A
- Style B
- Style C
- Style D

Outside Diameter of Tube

- 3.550
- 4.000
- 4.095
- 4.500

Distance Between Joint Centers in Inches:

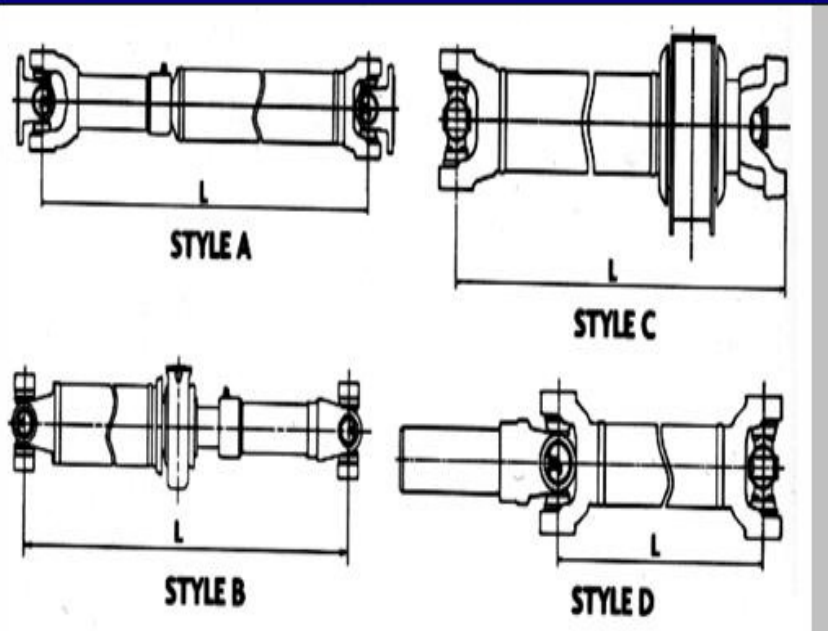
68

Maximum Safe Operating RPM:

1/2 True Critical Speed (RPM) (See Help Form)

Maximum Initial Balance RPM (See Help Form)

Calculate



Driveshaft 1/2 Critical Speeds Continued

Driveshaft ½ Critical Speed

- If this problem exist contact DSM (Service Engineering)
- One of the following or combination changes can be made to correct this issue:
  - Change to multiple driveshaft's
  - Change the length
  - Change the tube diameter
  - Change tube wall thickness
  - Change tube material

Driveshaft RPM = $\frac{\text{ENGINE RPM}}{\text{TRANSMISSION RATIO}}$

Example: $\frac{\text{2500 RPMS}}{\text{.65}}$ = 3846 RPMS of Driveshaft

Vibration Issues Meritor Drivelines

- If vehicle is in warranty and has a Meritor Driveline follow the procedures in TP-184
- Driveline Vibration MRWGLA01 Released 6-18
- See accelerometer mounting via model

M2 Mounting

Cascadia Mounting

Vibration Issues Meritor Drivelines continued

- Spec for M2 is 0.09g at seat base, Cascadia is 0.09g at steering column base
- As of now they say not to use a smartphone
- If reading are too high replace with soft cushion center bearing
- White paint along the base of the cushion.
- TDA CCB213 for 16 MXL and 17 MXL Series
- TDA HCB214 for 18 MXL and RPL Series
- Fill out appropriate Meritor claim form to file for warranty

16 MXL and 17 MXL Series

18 MXL and RPL Series

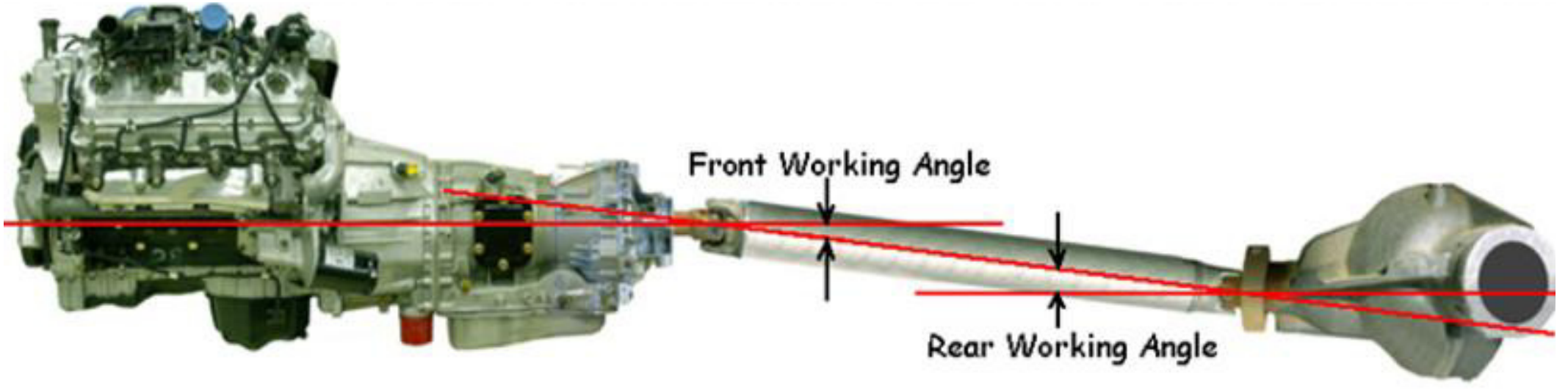
Driveline 2nd Order

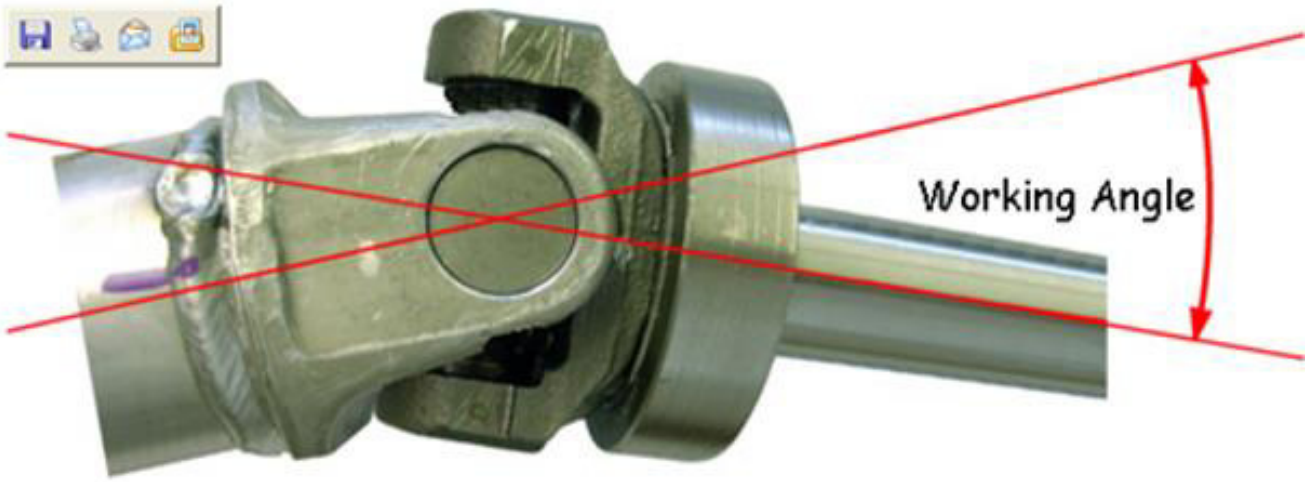
- **“U” joints**
- ✓ Loose, worn, lack of lube, out of phase

- **Incorrect Air Ride Height**
- ✓ Check according Freightliner LLC literature (workshop manuals or diagrams **module 621** Ride height)

- **Incorrect Working Angles**
- ✓ Verify the working angles are correct by using the Eaton DAA tool kit and software program

Driveline 2nd Order Working Angles





Discuss Theory of Non Uniform Velocity

Driveline Definitions

- **<u>Driveline Angle</u> –** (also called working angle) refers to the difference of the component angles of the drive side and driven side of a U-Joint. When the difference is zero each component on either side of the U-Joint will rotate at the same RPM. If the angle is not zero when the U-Joint is rotated, it will cause the component on the driven side to rotate at a changing rate.

- The driven component will increase and decrease speed twice each rotation. This constant changing rate is called **Torsional acceleration** and it's units is radians per second squared (rad/sec2) where 1 radian = 57 degrees. There is also a Inertial component generated that is measured in foot pounds (ft-lbs.).

Torsional Acceleration

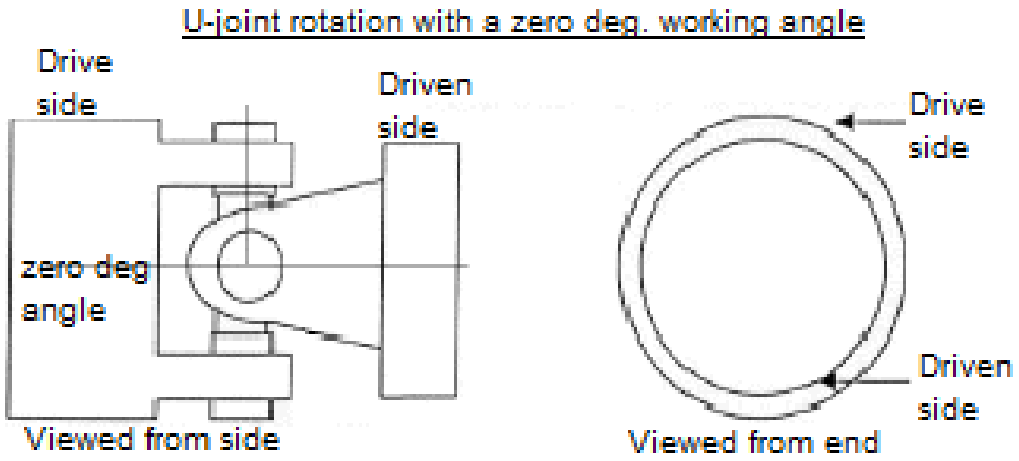


Figure 1

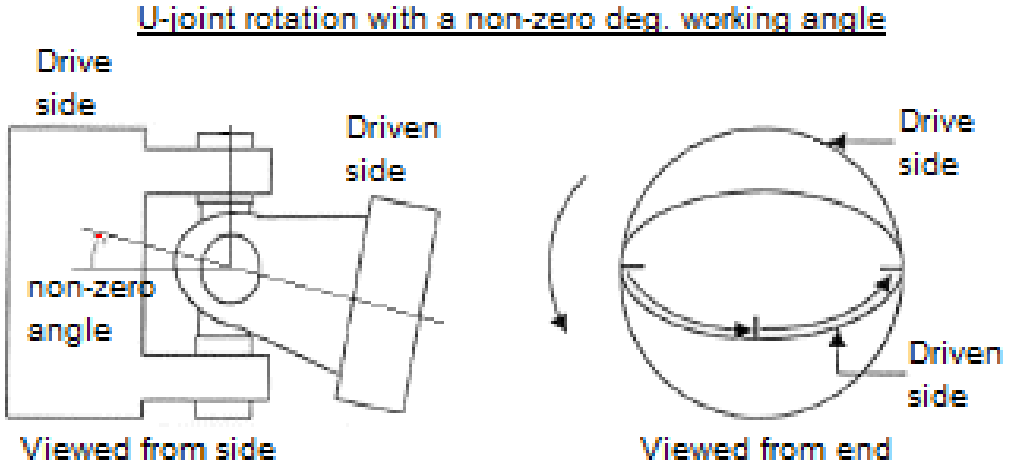


Figure 2

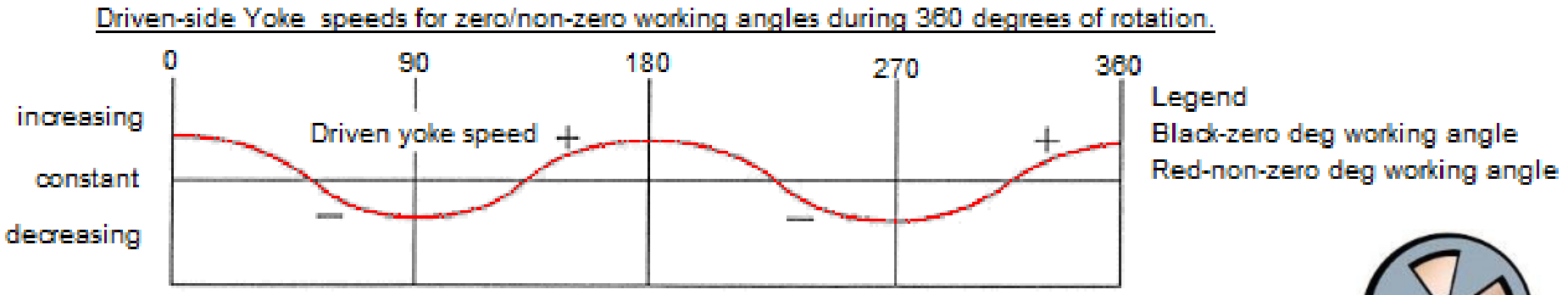
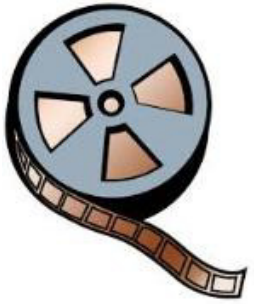


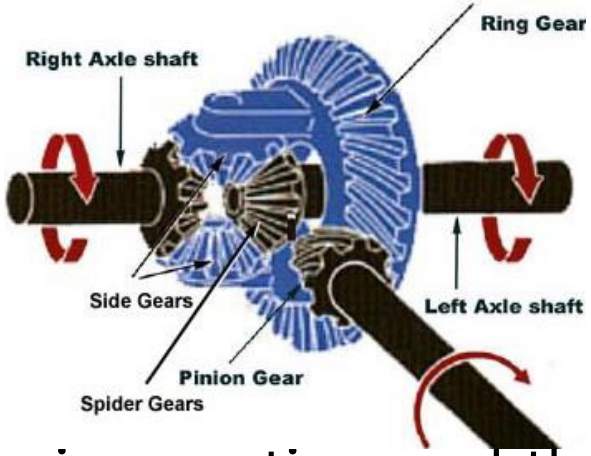
Figure 3



- Show Video or Demo on training aid non uniform velocity

Drive and Coast Inertias

- **Drive Inertia -** refers to the torque effect on the driveline with a U-Joint having a non zero working angle. Driveline inertia power is being supplied by the engine through the transmission to the drive train.



- **Coast Inertia -** is when the vehicle is coasting and the power is being supplied by the inertia of the vehicle pushing back through the axles and the rest of the drive train.

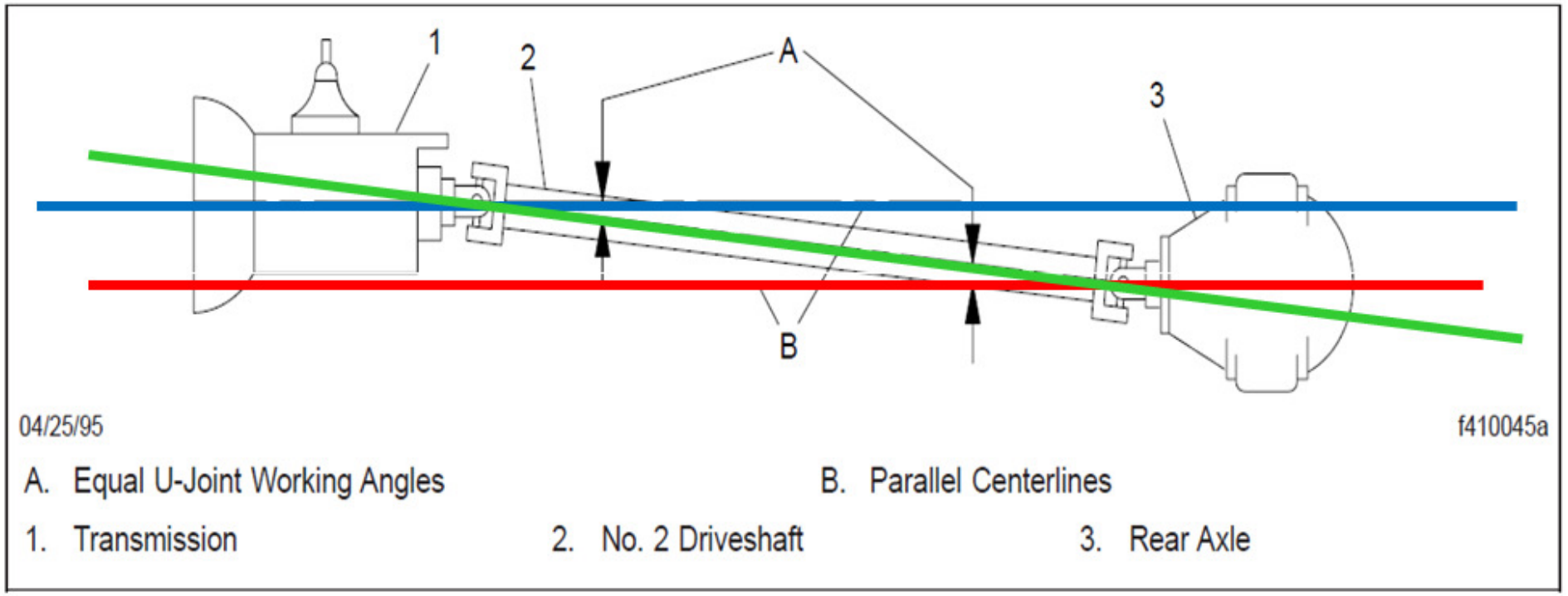
Driveline Configurations Parallel Arrangement

- The effect of U-Joint torsional can be cancelled out for each driveshaft by making sure the working angles of the U-Joint at either end of the driveshaft have the same working angle or within 1 degree. This can be accomplished by setting up the component in a **Parallel Arrangement**. Parallel arrangement is simply mounting two components at a same angle.

Transmission centerline

Rear axle centerline

Driveshaft centerline



Driveline Configuration Intersecting Plane

- It is not always possible to configure or mount all the components in a Parallel arrangement. An example would be the rear axles. If both rear axles were mounted on a different plane the tires would not contact the ground evenly to support the vehicle load. Therefore another method to reduce torsional vibration and inertias is called **Intersecting Plane.** An intersecting plane is where the mounting of the axles is such that the centerline of each axle intersects at mid point between both axles.

Rear axle centerline

Inter axle centerline

Intersection point

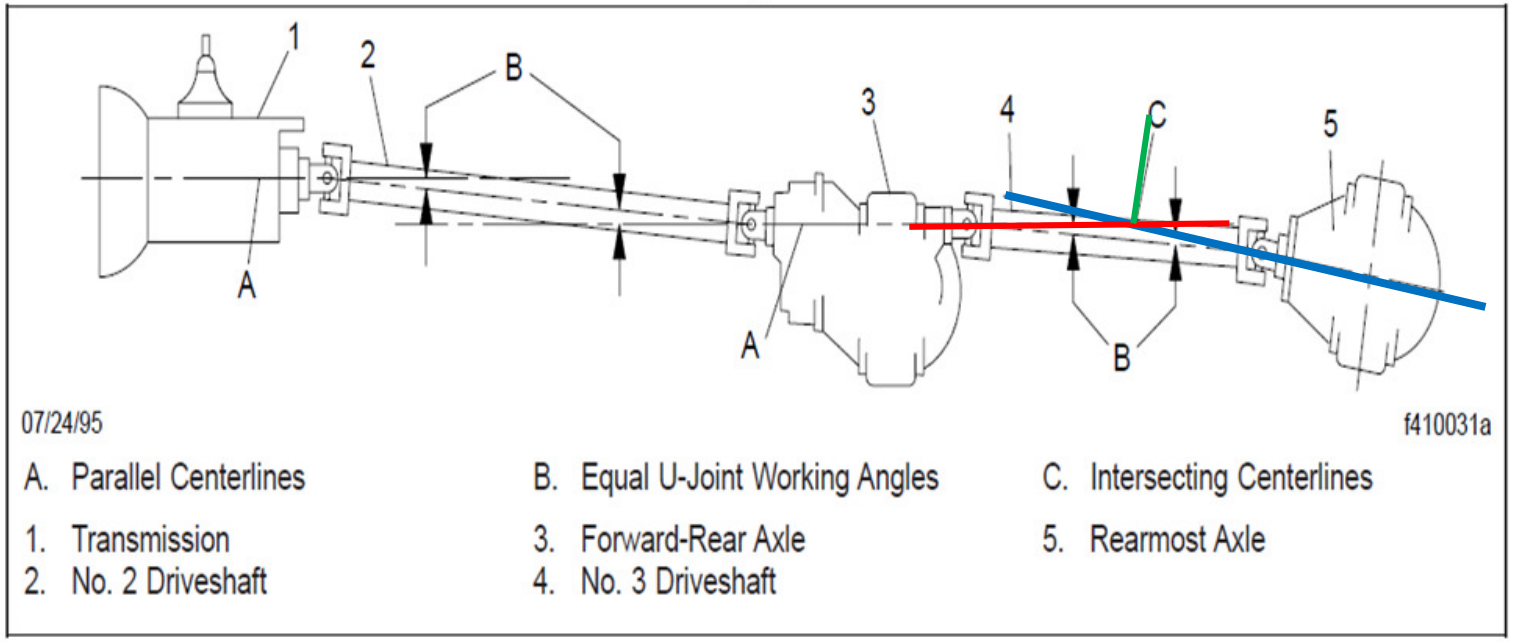


Fig. 2, Intersecting Planing Arrangements for Dual-Drive Vehicles

Symptoms and Effects of Incorrect Driveline Working Angles

➢ Growling during Acceleration or Deceleration

The growl is the gearing going through backlash at low torque or float conditions. This condition is more prevalent during deceleration or lightly loaded conditions.

➢ Typical driver complaints

- Noise and Vibration
- Growl under acceleration or deceleration
- Buzz transmitted up from the gear shift lever usually during float or while coasting.

Symptoms and Effects of Incorrect Driveline Working Angles

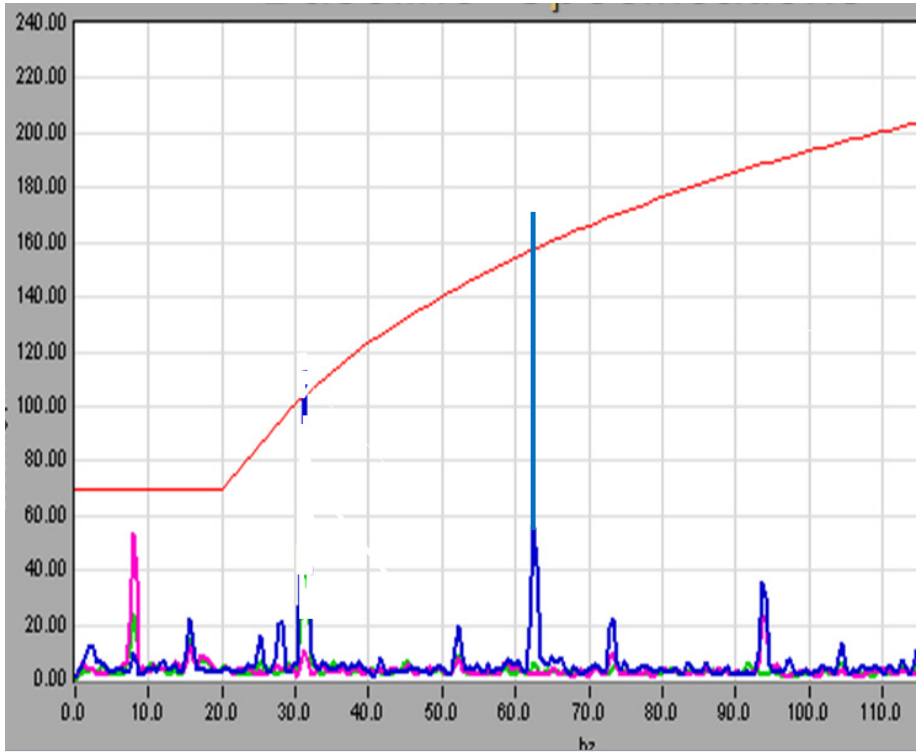
- **Decreased durability or failure of driveline components**

- **Transmission Failure Areas**
  - synchronizer pin breakage
  - synchronizer ring breakage
  - auxiliary drive gear and main shaft spline wear.
  - auxiliary drive gear and range sliding teeth fretting

- **Axle Failure Areas**
  - power dividers

- **Driveshaft Component Areas**
  - increased wear to carrier bearings
  - U-Joint fretting
  - slip spline wear

Driveline 2nd Order Sequence



- If the amplitude of the EVA is higher than the baseline and points to **Driveline 2nd order:**

1. Verify the ride height
2. Check the “U” Joint Phasing
3. Check the driveline working angles using the **Eaton DAA software program**. Make sure tires are properly inflated, vehicle is on a level surface, wheels chocked, transmission in neutral, and parking brake not set.
4. Adjust the working angles if necessary

Driveline Angle Analyzer Tools

- The Driveline Angle Analyzer tools can be purchased at **www.truckvibration.com** or **www.eaton.com** or by calling **269-743-9372**. The current cost is **$500**.
- Other vendors also sell software

Each kit includes:

- DAA software on CD-ROM. Supported operating systems include: Windows 2000, NT and XP.
- Digital Protractor – automatically displays driveline angle settings – no visual guesswork involved.
- "V" Block – to ensure accurate measurement on short driveshaft surfaces.
- 12 foot tape measure – to determine driveshaft lengths.
- Black Pelican tool kit case with foam insert.
- Simple installation and instructions.

Tools Required for Measuring Driveline Angles

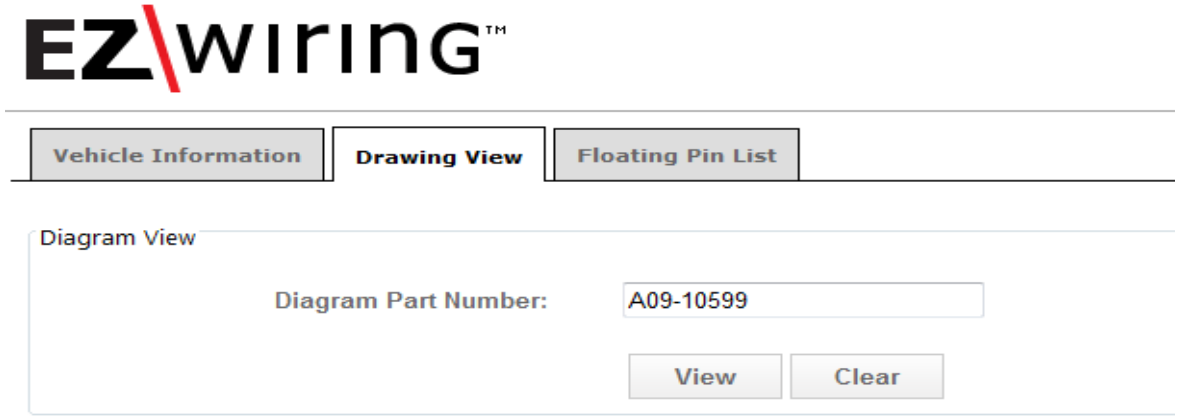
- Angle master/Digital Protractor
- Tape Measure
- V-Block
- Yoke Ruler
- Driveshaft Tube measurement tool or long eared caliper capable of measuring a 5 inch diameter driveshaft.

Information Needed for Driveline Software

- Critical information is needed when using the Eaton Driveline Angle Analyzer software. All Fields in **red** must be filled out in the vehicle information sheet. This is critical for correct calculations. The critical information includes:
  - **Main Driveline Series**
  - **Inter axle Driveline Series**
  - **Axle manufacture**
- Go to PartsPro to retain the driveline series, axle manufacture, and axle model.
- In PartsPro you can also obtain the driveshaft lengths, and if the driveshaft is phased.
- In EZ Wiring you can obtain the driveshaft outside diameter

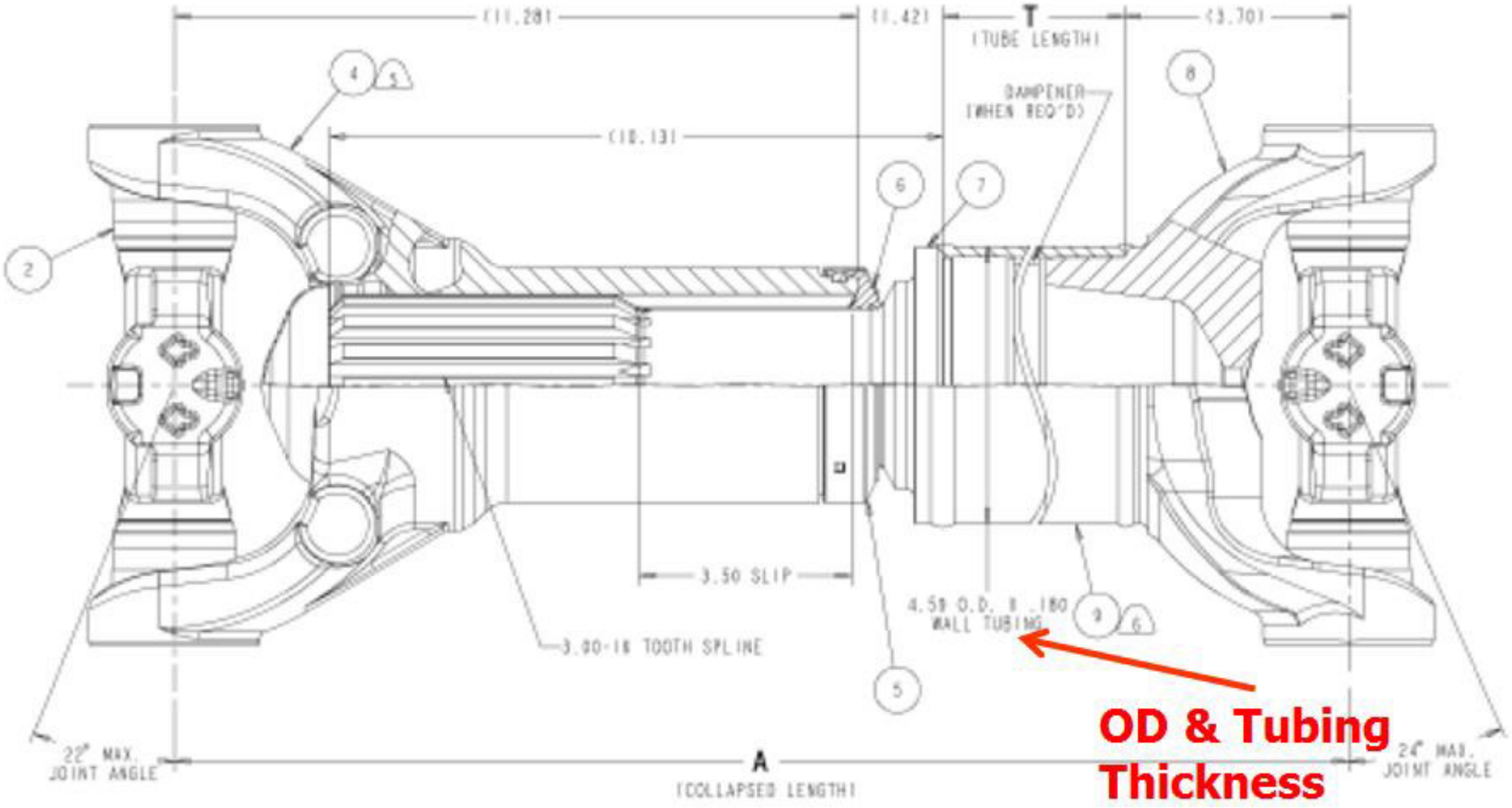
Driveshaft Information & Diagram Retrieval

- Important Driveshaft information can be obtained from the A09 Drawings.
- Retrieve from Parts Pro
- Enter the Driveshaft module number
- Select the Driveshaft
- Go to EZ wiring and leave off the last three digits example A09-10599-000 leave of the 000 when entering diagram in EZ wiring



Module	Description
386	Driveshaft Main Rear Axle Input
388	Driveshaft interaxle
391	Driveshaft & Midship Brg. Forward #1

Driveline Wall Tubing Thickness



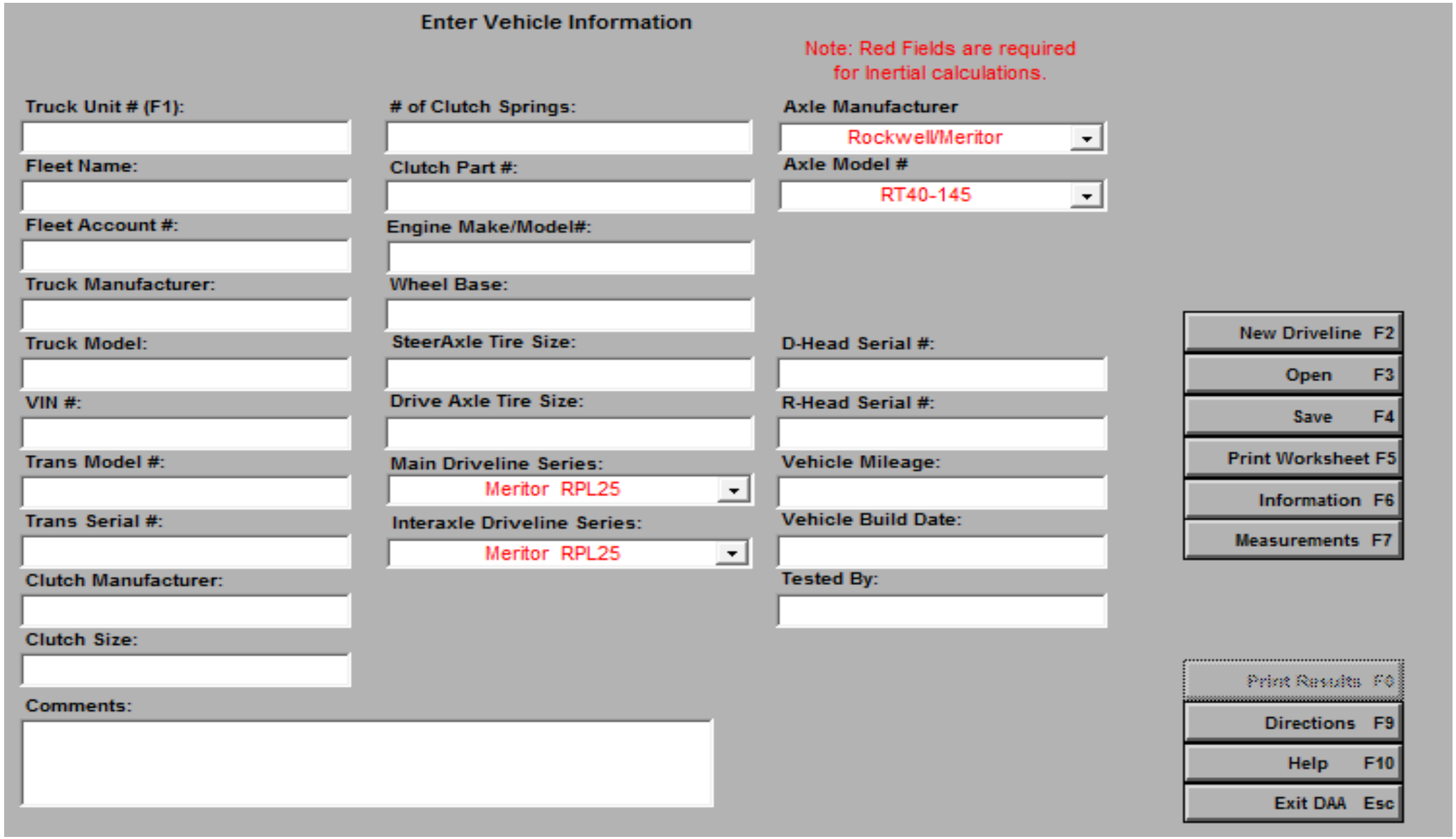
Driveline Software Worksheet Information & Driveshaft Measurement

- The measurement sheet also requires all the **red** fields to be filled out so that driveline calculations can be figured. Include the following:

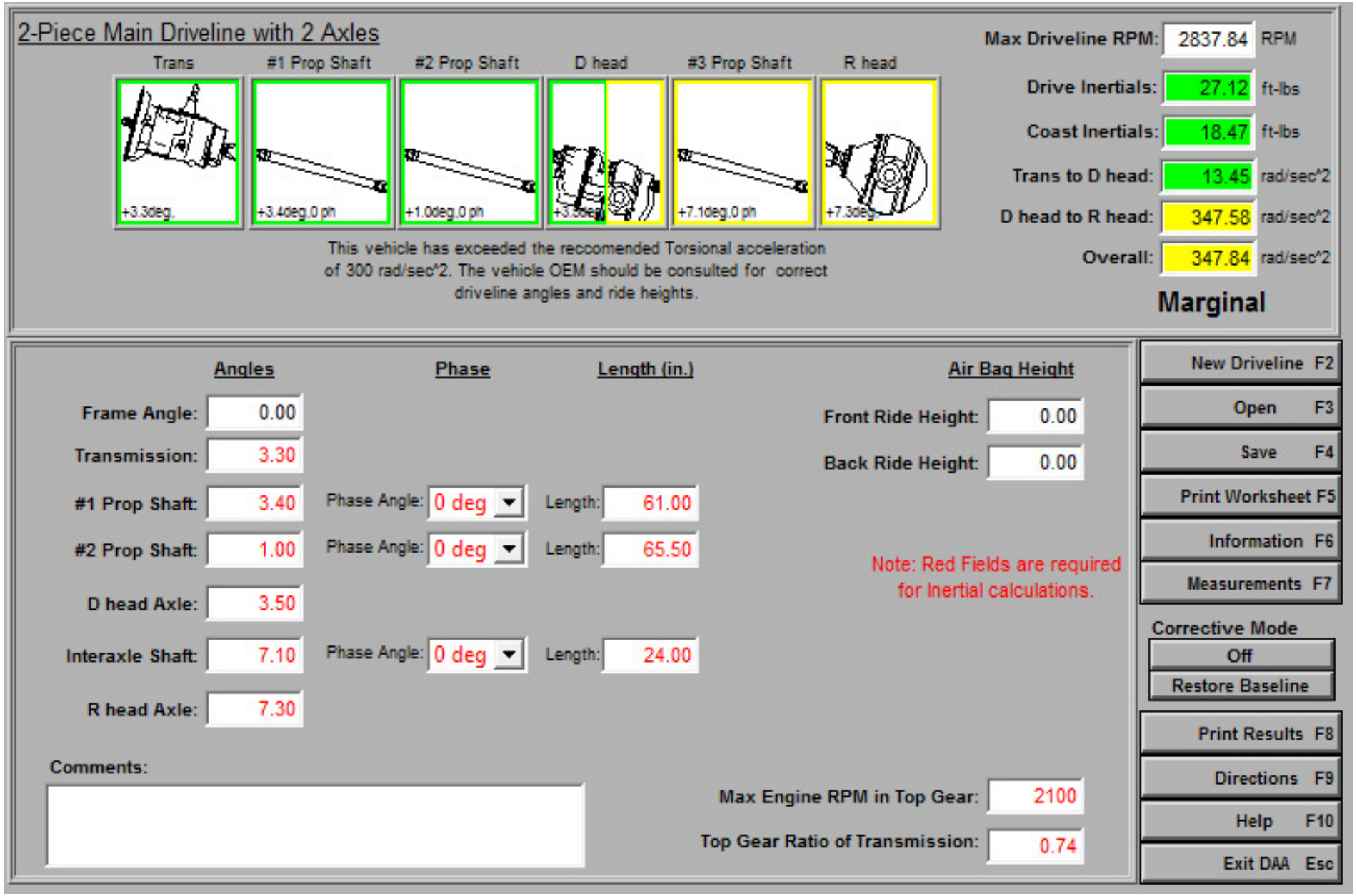
- **Transmission,#1propshaft, and #2 propshaft if applicable.**
- **Drive and rear head axle angle if applicable.**
- **Inter axle propshaft angle if applicable.**
- **Phase angle of each driveshaft**
- **Length of each drive shaft.**
- **Maximum Engine RPM in Top Gear**
- **Top gear ratio of transmission.**

- **Positive Angle**- A positive angle is when the end closest to the front of the vehicle is higher than the end farthest from the vehicle.
- **Negative Angle**- A negative angle is when the end closest to the front of the vehicle is lower than the end farthest from the vehicle.

Enter Driveline Information in Software



Enter Driveline Information in Software



Torsional and Inertia Readings & Rules of Operating Angles

Torsional in Rads/sec^2				Inertias Drive and Coast			
0	to	25	= Good	0	to	200	= Good
201	to	1,000	= Marginal	26	to	100	= Marginal
Above		100	= Fail	Above		1,000	= Fail

➢ 3 Rules of Operating Angles

1. All working angles must be at least 1 degree. This ensures the needle rollers in the “U” joint will rotate and act as a bearing.

2. The operating angles at each end of the same driveshaft must be within 1 degree of each other.

3. All operating angles should be a maximum of 3 degrees. This provides the absolute minimum amount of vibration in the driveline.

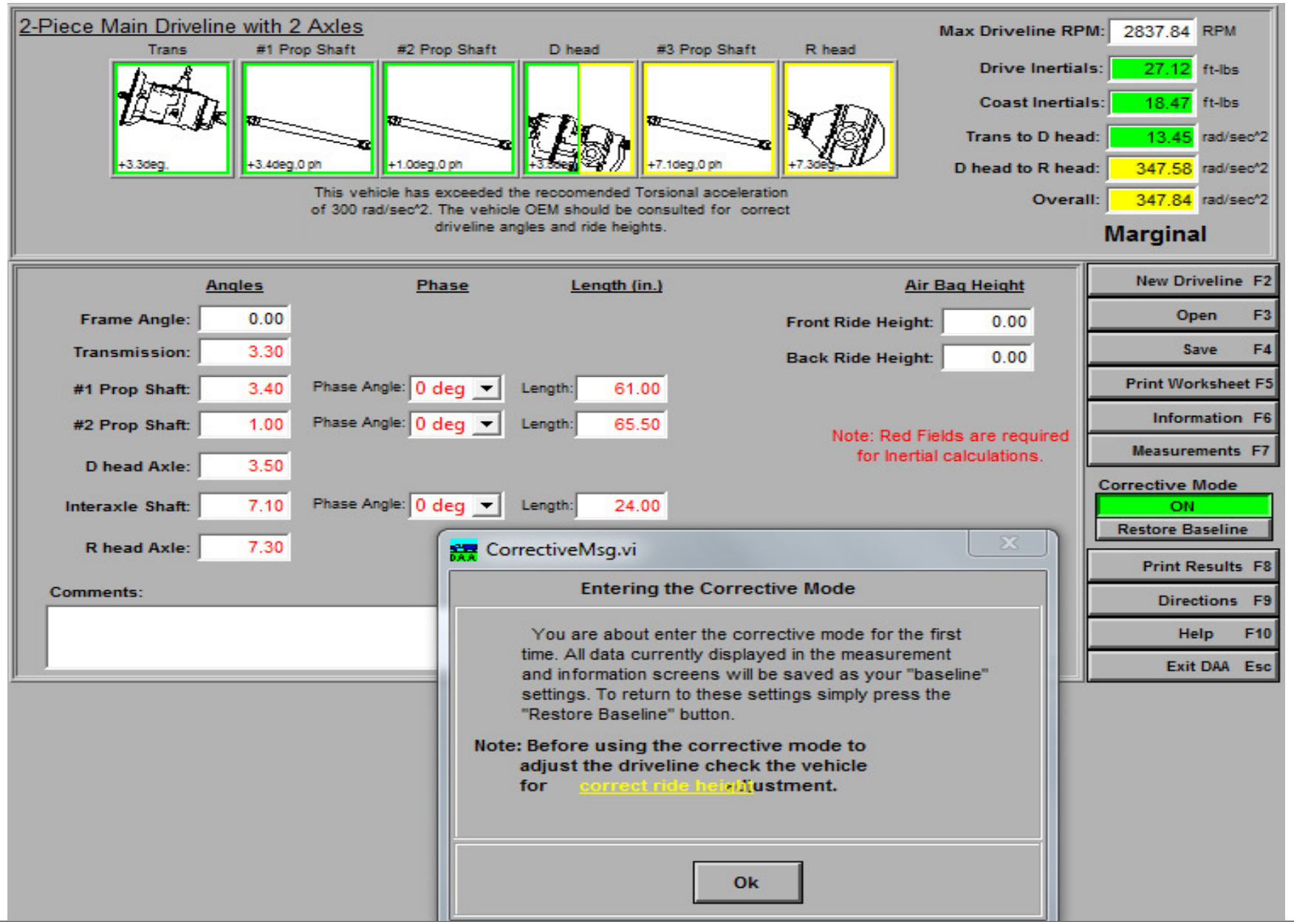
Correction Mode in the Driveline Software

- Once all fields required on both sheets are entered the driveline calculation occurs and becomes active. Portions of the driveline will be colored to indicate its condition. The colors are:

Green = Good
Yellow = Marginal
Red = Fail

- Click on Correction Mode
- Save Baseline reading for before and after readings.
- Items in **Red** and **Yellow** need to be altered.

Correction Mode



Adjusting to Correct Improper Working Angles

- If axle needs to be adjusted change by shim selection in axle seats.
- Axle seat diagrams are found in module 431.

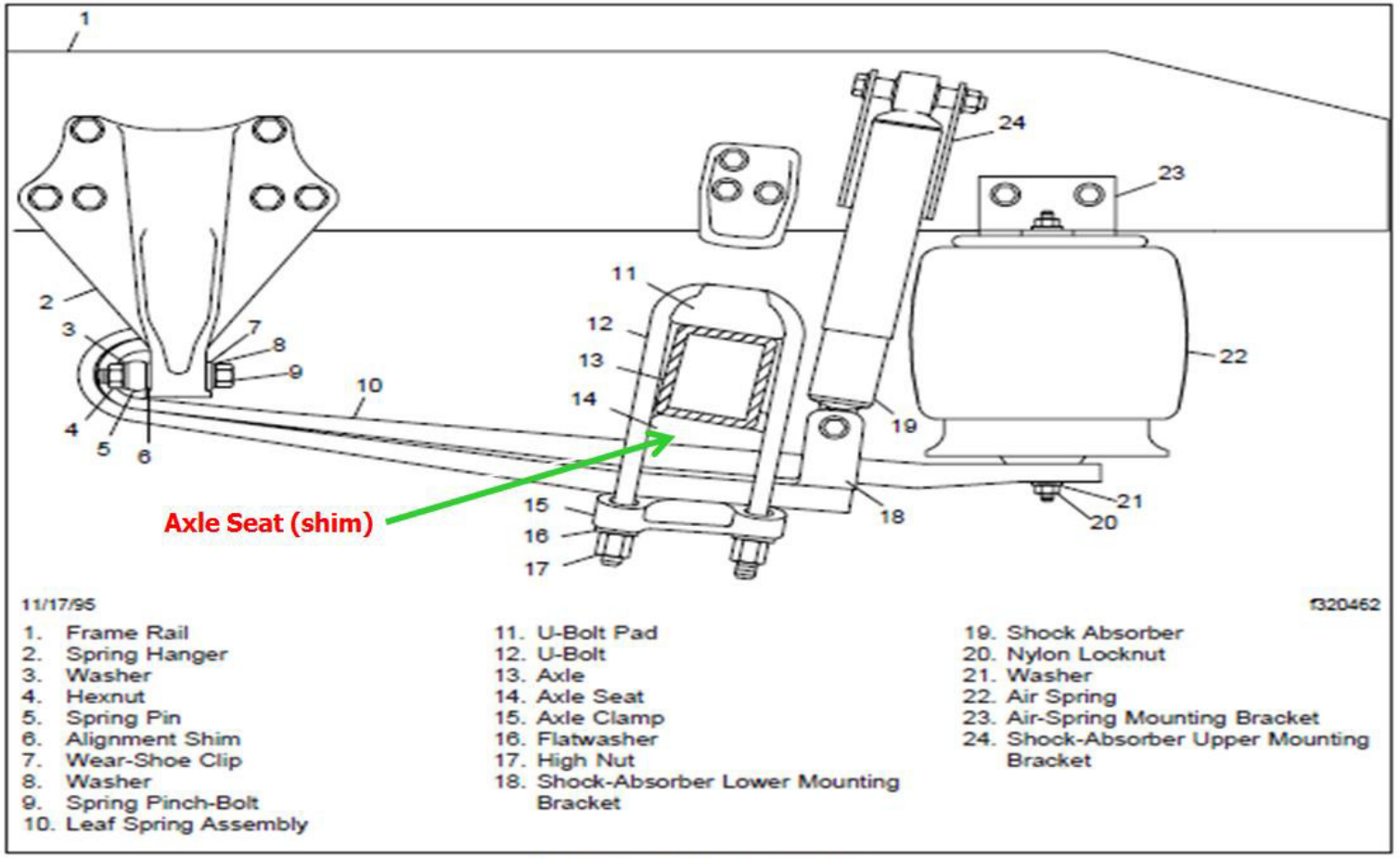


Fig. 1, Rear Axle Suspension

Diagram L16-14130 Axle Seats

STANDARD AXLE SEATS

ITEM	SUSP	AXLE	APPLIC	HIGH PLANE ANGLE	SEAT ANGLE		THICK SIDE OF SEAT		AXLE SEAT				TOP PAD			
					FWD	AFT	FWD AXLE	AFT AXLE	LF	RF	LR	RR	LF	RF	LR	RR
1	40K	RT34/40/44-145;RT40/46-160/164	51/55"	NO	3°	-5 5°	AFT	FWD	16-14049-000	16-14049-000	16-14051-000	16-14051-000	16-14054-000	16-14054-000	16-14055-000	16-14055-000
2	40K	ETN 404	51/55"	NO	3°	-4.5°	AFT	FWD	16-14049-000	16-14049-000	16-14050-000	16-14050-000	16-14054-000	16-14054-000	16-14055-000	16-14055-000
3	40K	RT34/40/44-145 & 404	59"	NO	3°	3°	AFT	AFT	16-14049-000	16-14049-000	16-14049-000	16-14049-000	16-14054-000	16-14054-000	16-14054-000	16-14054-000
4	40K	RT40/46-160	59"	NO	3°	-3°	AFT	FWD	16-14049-000	16-14049-000	16-14049-000	16-14049-000	16-14054-000	16-14054-000	16-14054-000	16-14054-000
5	40K	ETN 461	51/55"	NO	3°	-3°	AFT	FWD	16-14059-000	16-14059-001	16-14059-001	16-14059-000	16-14054-000	16-14054-003	16-14054-003	16-14054-000
6	40K	ETN 461	59"	NO	3°	3°	AFT	AFT	16-14059-000	16-14059-001	16-14059-002	16-14059-000	16-14054-000	16-14054-003	16-14054-003	16-14054-000
7	40K	ETNSUPER40/462	51/66"	NO	3°	-4 5°	AFT	FWD	16-14049-000	16-14049-001	16-14609-000	16-14050-000	16-14064-000	16-14064-000	16-14066-000	16-14066-000
8	40,20,21K	RS23-160/23-186 & TAG /1\	3°	NO	3°	3°	AFT	AFT	16-14049-000	16-14049-000	16-14049-000	16-14049-000	16-14054-000	16-14054-000	16-14054-000	16-14054-000
9	40,20K	RS23-180 & TAG	3°	NO	3°	3°	AFT	AFT	16-14049-002	16-14049-000	16-14049-000	16-14049-000	16-14054-004	16-14054-000	16-14054-000	16-14054-000
10	40,20K	ETN23105 & TAG	3°	NO	3°	3°	AFT	AFT	16-14059-002	16-14059-000	16-14049-000	16-14049-000	16-14054-005	16-14054-000	16-14054-000	16-14054-000
11	40,20K	RS23-160/23-186 & TAG /1\	5°	NO	1°	3°	AFT	AFT	16-14060-000	16-14060-000	16-14049-000	16-14049-000	16-14055-000	16-14055-000	16-14054-000	16-14054-000
12	40,20K	RS23-180 & TAG	5°	NO	1°	3°	AFT	AFT	16-14060-001	16-14060-000	16-14049-000	16-14049-000	16-14055-001	16-14055-000	16-14054-000	16-14054-000
13	40,20K	ETN23105 & TAG	5°	NO	1°	3°	AFT	AFT	16-14060-003	16-14060-002	16-14049-000	16-14049-000	16-14055-002	16-14055-000	16-14054-000	16-14054-000
14	40K	RT34/40/44-145;RT40/46-160/164	51/66"	YES	2°	-6 5°	AFT	FWD	16-14140-000	16-14140-000	16-14061-000	16-14061-000	16-14064-000	16-14064-000	16-14066-000	16-14066-000
15	40K	ETN 404	51/55"	YES	2°	-4.5°	AFT	FWD	16-14140-000	16-14140-000	16-14050-000	16-14050-000	16-14054-000	16-14054-000	16-14055-000	16-14055-000
16	40K	RT34/40/44-145 & 404	59"	YES	2°	3°	AFT	AFT	16-14140-000	16-14140-000	16-14049-000	16-14049-000	16-14054-000	16-14054-000	16-14054-000	16-14054-000
17	40K	RT40/46-160	59"	YES	2°	-3°	AFT	FWD	16-14140-000	16-14140-000	16-14049-000	16-14049-000	16-14054-000	16-14054-000	16-14054-000	16-14054-000
18	40K	RT34/40/44-145	51" LOW HGT	NO	2°	-6 5°	AFT	FWD	16-14140-000	16-14140-000	16-14601-000	16-14601-000	16-14302-000	16-14302-000	16-14303-000	16-14303-001
19	40K	ETN 404	51" LOW HGT	NO	2°	-5 5°	AFT	FWD	16-14140-000	16-14140-000	16-14051-000	16-14051-000	16-14302-000	16-14302-000	16-14303-000	16-14303-001
20	40K	RT34/40/44-145	51" MID HGT	NO	4.5°	-5 5°	AFT	FWD	16-14050-000	16-14050-000	16-14051-000	16-14051-000	16-14302-000	16-14302-000	16-14303-000	16-14303-001
21	40K	ETN 404	51" MID HGT	NO	4.5°	-4°	AFT	FWD	16-14050-000	16-14050-000	16-14609-000	16-14609-000	16-14302-000	16-14302-000	16-14303-000	16-14303-001
22	40K	ETN 402	51/55"	NO	3°	-3°	AFT	FWD	16-14049-000	16-14049-001	16-14049-001	16-14049-000	16-14054-000	16-14054-003	16-14054-003	16-14054-000
23	40K	ETN 402	59"	NO	3°	3°	AFT	AFT	16-14049-000	16-14049-001	16-14049-002	16-14049-000	16-14054-000	16-14054-003	16-14054-003	16-14054-000
24	40K	S0100	51/55"	NO	3°	-3°	AFT	FWD	16-14049-000	16-14049-001	16-14049-001	16-14049-000	16-14054-000	16-14054-002	16-14054-002	16-14054-000
25	23K	ETN23105	6 3°	--	1°	-	AFT	-	16-14060-003	16-14060-000	----	----	16-14783-000	16-14783-000	----	----
26	23K	ETN23105	5 3°	--	2°	-	AFT	-	16-14139-006	16-14139-003	----	----	16-14783-000	16-14783-000	----	----
27	23K	ETN23105	4 3°	--	3°	-	AFT	-	16-14059-002	16-14059-000	----	----	16-14783-000	16-14783-000	----	----
28	23K	ETN23080	6 3°	--	1°	-	AFT	-	16-14060-000	16-14060-000	----	----	16-14783-000	16-14783-000	----	----
29	23K	ETN23080	5.3°	--	2°	-	AFT	-	16-14139-003	16-14139-003	----	----	16-14783-000	16-14783-000	----	----
30	23K	ETN23080	4.3°	--	3°	-	AFT	-	16-14059-000	16-14059-000	----	----	16-14783-000	16-14783-000	----	----
31	23K	RS23-160/23-186 /1\	6.3°	--	0°	-	AFT	-	16-14661-000	16-14661-000	----	----	16-14783-000	16-14783-000	----	----
32	23K	RS23-160/23-186 /1\	5 3°	--	1°	-	AFT	-	16-14060-000	16-14060-000	----	----	16-14783-000	16-14783-000	----	----
33	23K	RS23-160/23-186 /1\	4 3°	--	2°	-	AFT	-	16-14140-000	16-14140-000	----	----	16-14783-000	16-14783-000	----	----
34	23K	RS23-180	6 3°	--	1°	-	AFT	-	16-14060-001	16-14060-000	----	----	16-14783-000	16-14783-000	----	----
35	23K	RS23-180	4 3°	--	2°	-	AFT	-	16-14139-001	16-14140-000	----	----	16-14783-000	16-14783-000	----	----
36	40K	MT40-143	51/55/59°	NO	3°	3°	AFT	AFT	16-14049-000	16-14049-000	16-14049-000	16-14049-000	16-14054-000	16-14054-000	16-14054-000	16-14054-000
37	40K	MT40-143	51/55/59°	YES	2°	3°	AFT	AFT	16-14140-000	16-14140-000	16-14049-000	16-14049-000	16-14054-000	16-14054-000	16-14054-000	16-14054-000

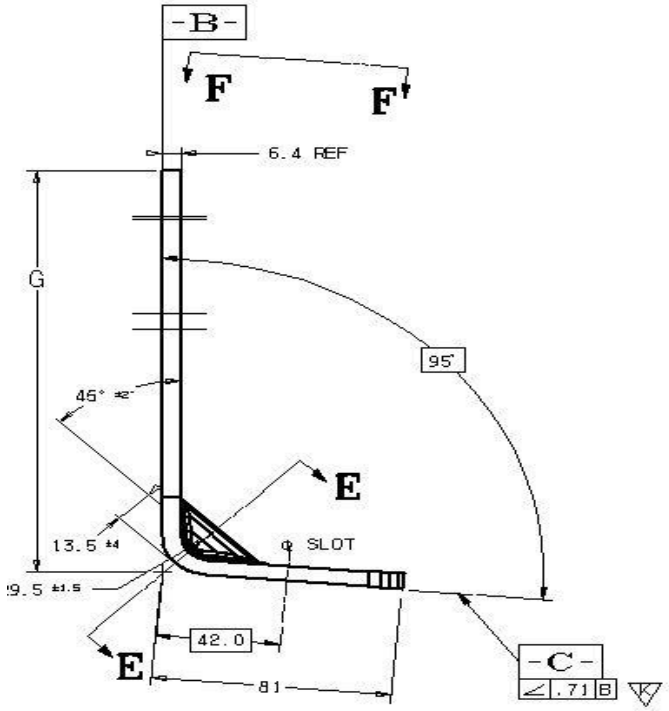
If Drawings are no longer available via PartsPro/EZ Wiring Use View CAD to access.

Diagram L16-14130 Axle Seats

ITEM	SUSP	AXLE	APPLIC	HIGH PLANE ANGLE	SEAT ANGLE		THICK SIDE OF SEAT	
					FWD	AFT	FWD AXLE	AFT AXLE
1	40K	RT34/40/44-145;RT40/46-160/164	51/55"	NO	3°	-5.5°	AFT	FWD
2	40K	ETN 404	51/55"	NO	3°	-4.5°	AFT	FWD
3	40K	RT34/40/44-145 & 404	59"	NO	3°	3°	AFT	AFT
4	40K	RT40/46-160	59"	NO	3°	-3°	AFT	FWD
5	40K	ETN 461	51/55"	NO	3°	-3°	AFT	FWD
6	40K	ETN 461	59"	NO	3°	3°	AFT	AFT
7	40K	ETNSUPER40/462	51/55"	NO	3°	-4.5°	AFT	FWD
8	40,20,21K	RS23-160/23-186 & TAG 1	3°	NO	3°	3°	AFT	AFT
9	40,20K	RS23-180 & TAG	3°	NO	3°	3°	AFT	AFT
10	40,20K	ETN23105 & TAG	3°	NO	3°	3°	AFT	AFT
11	40,20K	RS23-160/23-186 & TAG 1	5°	NO	1°	3°	AFT	AFT
12	40,20K	RS23-180 & TAG	5°	NO	1°	3°	AFT	AFT
13	40,20K	ETN23105 & TAG	5°	NO	1°	3°	AFT	AFT
14	40K	RT34/40/44-145;RT40/46-160/164	51/55"	YES	2°	-5.5°	AFT	FWD
15	40K	ETN 404	51/55"	YES	2°	-4.5°	AFT	FWD
16	40K	RT34/40/44-145 & 404	59"	YES	2°	3°	AFT	AFT
17	40K	RT40/46-160	59"	YES	2°	-3°	AFT	FWD
18	40K	RT34/40/44-145	51" LOW HGT	NO	2°	-6.5°	AFT	FWD

Driveline Adjustments Continued/Carrier Bearing Brackets

- If the front part of the drive train needs adjustment you may have to select a different size mid-ship (carrier) bearing bracket.
- The different size brackets can be found in module 385.
- Drawings for mid-ship support brackets will usually include several bracket lengths on the same drawing.



265.9	240.5	215.1	189.7	164.3	138.9	'G' DIMENSION
ITEM NUMBER 09-10213-005	ITEM NUMBER 19-10213-004	ITEM NUMBER 09-10213-003	ITEM NUMBER 09-10213-002	ITEM NUMBER 09-10213-001	ITEM NUMBER 09-10213-000	
DESCRIPTION SUPT-M/SHIP BRG,5.0 DEG AIR MT	DESCRIPTION SUPT-M/SHIP BRG,5.0 DEG AIR MT	DESCRIPTION SUPT-M/SHIP BRG,5.0 DEG AIR MT	DESCRIPTION SUPT-M/SHIP BRG,5.0 DEG AIR MT	DESCRIPTION SUPT-M/SHIP BRG,5.0 DEG AIR MT	DESCRIPTION SUPT-M/SHIP BRG,5.0 DEG AIR MT	

FREIGHTLINER LLC

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MATERIAL APPROVAL AJS	DATE 05/12/97	UNLESS OTHERWISE NOTED, DIMENSIONS AND TOLERANCES ARE DEFINED ACCORDING TO ANSI STANDARD Y14.5M-1982, WITH EXCEPTIONS PER FREIGHTLINER EOM SECT 307.	
DRAWN BY WJK	DATE 07/25/96		
CHECKED BY RCF	DATE 07/25/96		
RESPONSIBLE ENGINEER WJK	DATE 07/25/96	THIRD ANGLE PROJECTION	UNITS OF MEASURE MM
APPROVED BY JSB	DATE 07/25/96	MFG ENGR/PURCH MENT B.GERKINS	DATE 05/12/97

DESCRIPTION
SUPT-M/SHIP BRG,5.0 DEG AIR MT
SUPPLEMENTARY DESCRIPTION
39201

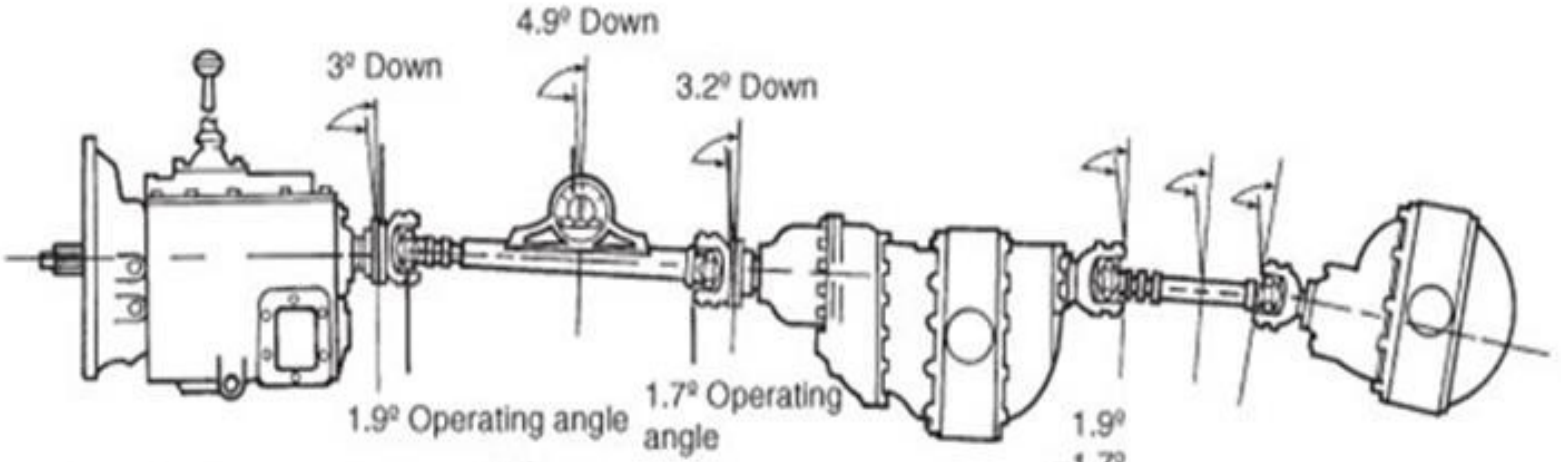
ITEM/DRAWING NUMBER	REVISION LETTER	SHEET NUMBER
09-10213	C	1 OF 2

Manually Calculating Working Angles Without Software

- Positive and Positive = Subtract
- Negative and Negative = Subtract
- Positive and Negative = Add

Example:

+3.3	-2.5	+4.1
+2.0	-1.1	-1.2
=1.3	=1.4	=5.3



Engine Vibration Excitations

- There are two basic excitations caused by engines
- **Inertia** pertains to balancing (mass) and vibrations caused by imbalanced components.
- **Combustion** pertains to forces or firing related vibrations caused by components flexing or possibly not firing equally.

Engine Order Mathematics

Why Series 60 engine have vibration at certain orders?

The Series 60 is an "even fire" six cylinder engine. Every revolution of the engine takes the crankshaft, rod, and pistons through a complete cycle. Thus, crankshaft imbalance produces first order vibration. Other multiples of first order (2^{nd}, 3^{rd}, etc.) are also produced by the rotation of the crankshaft due to the motion of the pistons and rods.

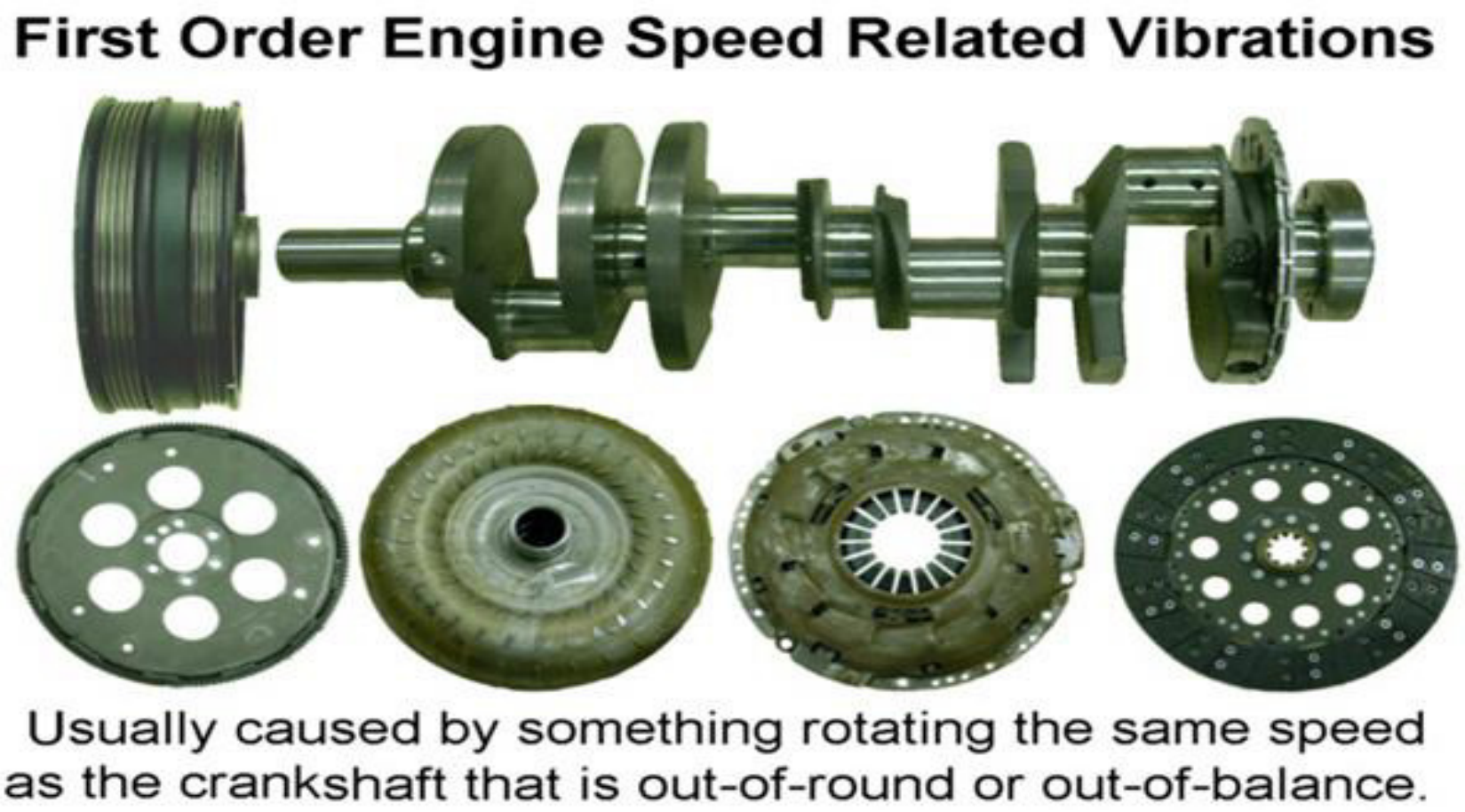
Every two revolutions the cam/injector system goes through a cycle. Thus, the cam drive produces half order vibration. Other multiples of half order (1.0, 1.5, 2.0, etc.) are also produced by motion of the cam drive.

Every two revolutions (720 degrees) a cylinder goes through a complete combustion cycle (intake, compression, ignition, and exhaust), but this is an even fire engine, so every 120 degrees (720/6) the combustion process repeats. Thus, combustion produces $1/3^{rd}$ order vibration and multiples ($1/6^{th}$, $1/9^{th}$, $1/12^{th}$ order, etc.).

The Series 60 engine has an air pump that produces vibration at 1.2 engine order because it is driven by a gear train at 1.2 times the speed of the crankshaft. Other gear train component order are calculated the same way.

Engine Order Evaluation

- **Engine 1st order is a balance condition check:**
  - torsional damper
  - crankshaft
  - torque converter
  - flex plate
  - clutch assembly



Engine ½ Orders

- ½ engine order may indicate an issue with cylinder firing or other engine accessory.

- If ½ engine order is displayed on the vibrate 5.1 graph the following should be done:

- Perform cylinder cut out test to determine faulty cylinder. If test indicates a problem with a cylinder further diagnosis will have to be performed to correct the problem.

- **Note:** a camshaft with bad bearings can also cause ½ order issues.

Engine 2nd Order and Above Source Analysis

- Engine/exhaust vibrations; these types of vibrations especially relating to fuel or high torque fall into the 4-4.5 order type of vibration.
- Check for good engine or transmission mounts and proper clearance according to **SB 01-78**
- Check for exhaust shorting to cab (cab mounted exhaust is very susceptible to this problem)
- **Note:** Exhaust noise and vibrations getting into the cab may require extensive exhaust modifications and mounting changes

Engine 2nd Order and Above Source Analysis: Cab/Engine Mounts

- Always check for proper cab mounting and making sure the cab has good isolation.
- Engine, transmission, cab, and body mounts are **transfer paths**. A transfer path can also be anything component that touches (i.e. exhaust system, running board) the vibration source and the responding component that the driver notices or feels. Whenever normal engine vibrations are felt in the cab, the transfer path should be repaired rather than the source.

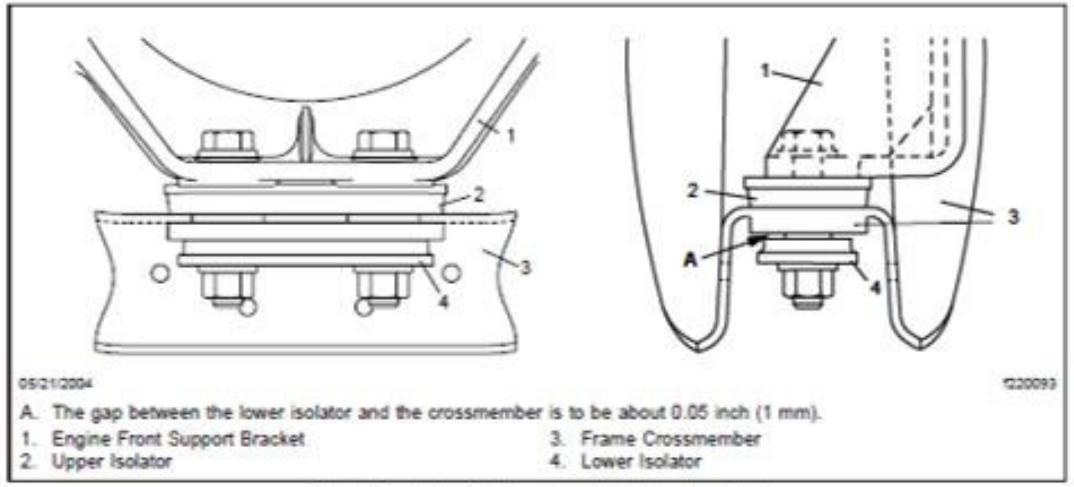


Fig. 1, Front Engine Mount and Isolators (typical)

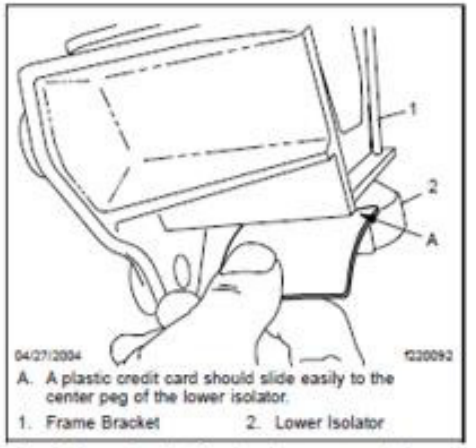


Fig. 3, Measuring the Gap (engine rear mount shown)

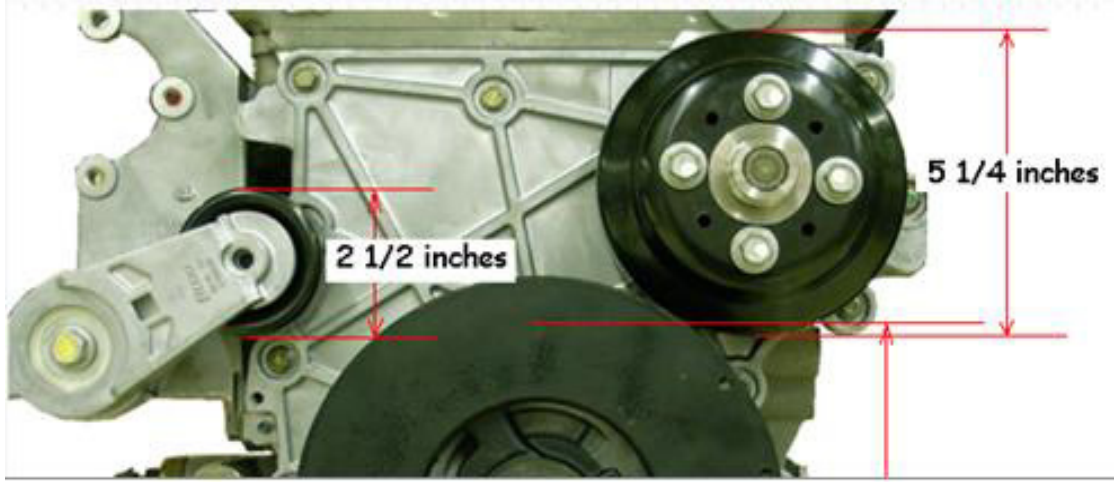
Engine 2nd Order and Above Source Analysis:

- You can use the additional EVA sensor to check the **mount isolation** by installing a sensor on both side of the mount. Compare the readings to see if the isolator is doing it's job by dampening. There should be a noticeable reading before and after the isolator. If not the isolator may be grounding out.

Tuned Mass Absorber

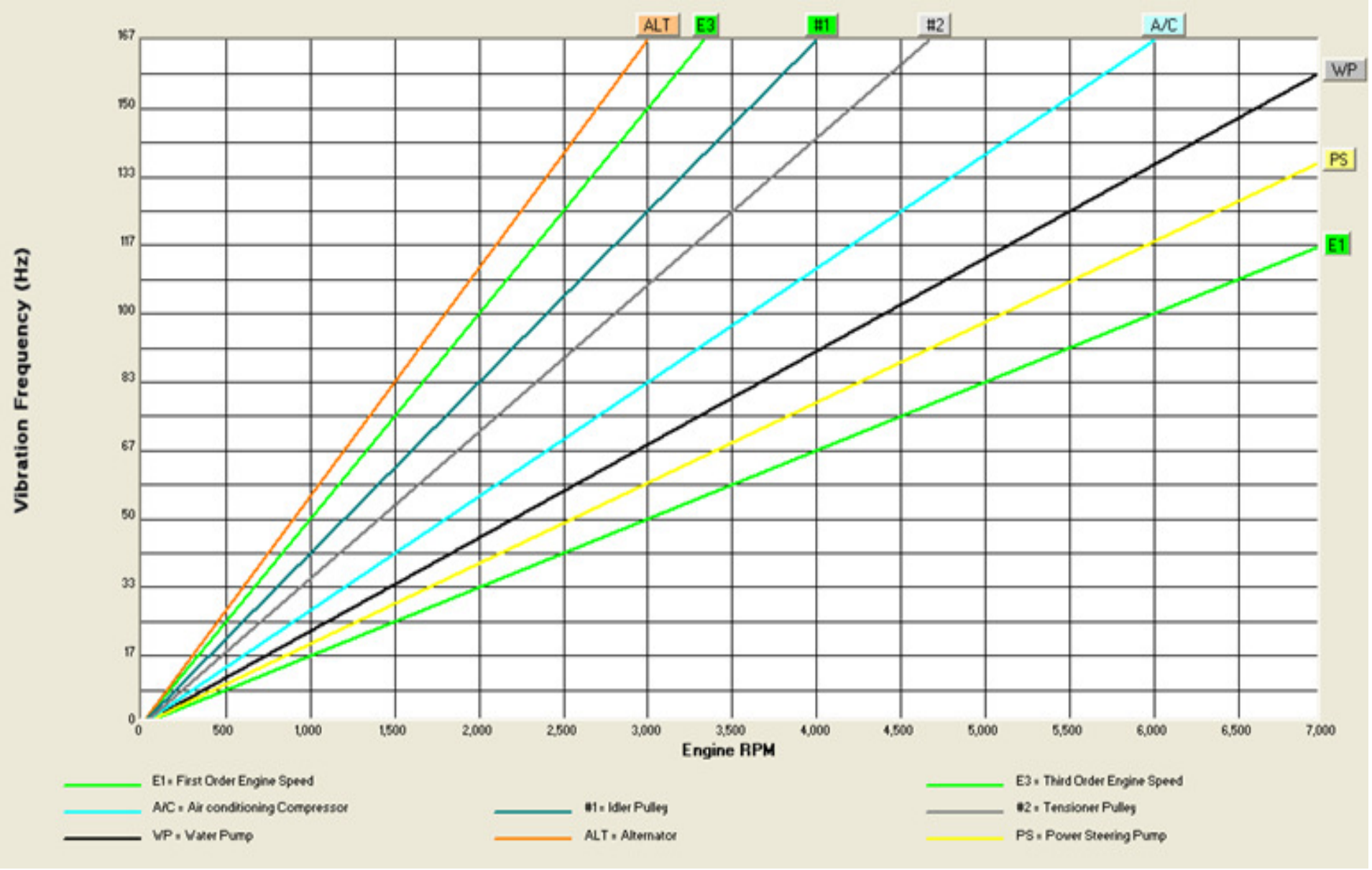
Engine Accessory Diagnostics

- If a high amplitude is discovered and nothing lines up with the standard graph there is a good possibility the source may be from an accessory on the engine.
- To diagnosis this issue you must measure and enter the pulley diameters from the engine's accessories in the Vibrate 5.1 software.
- Provided Demo of Software

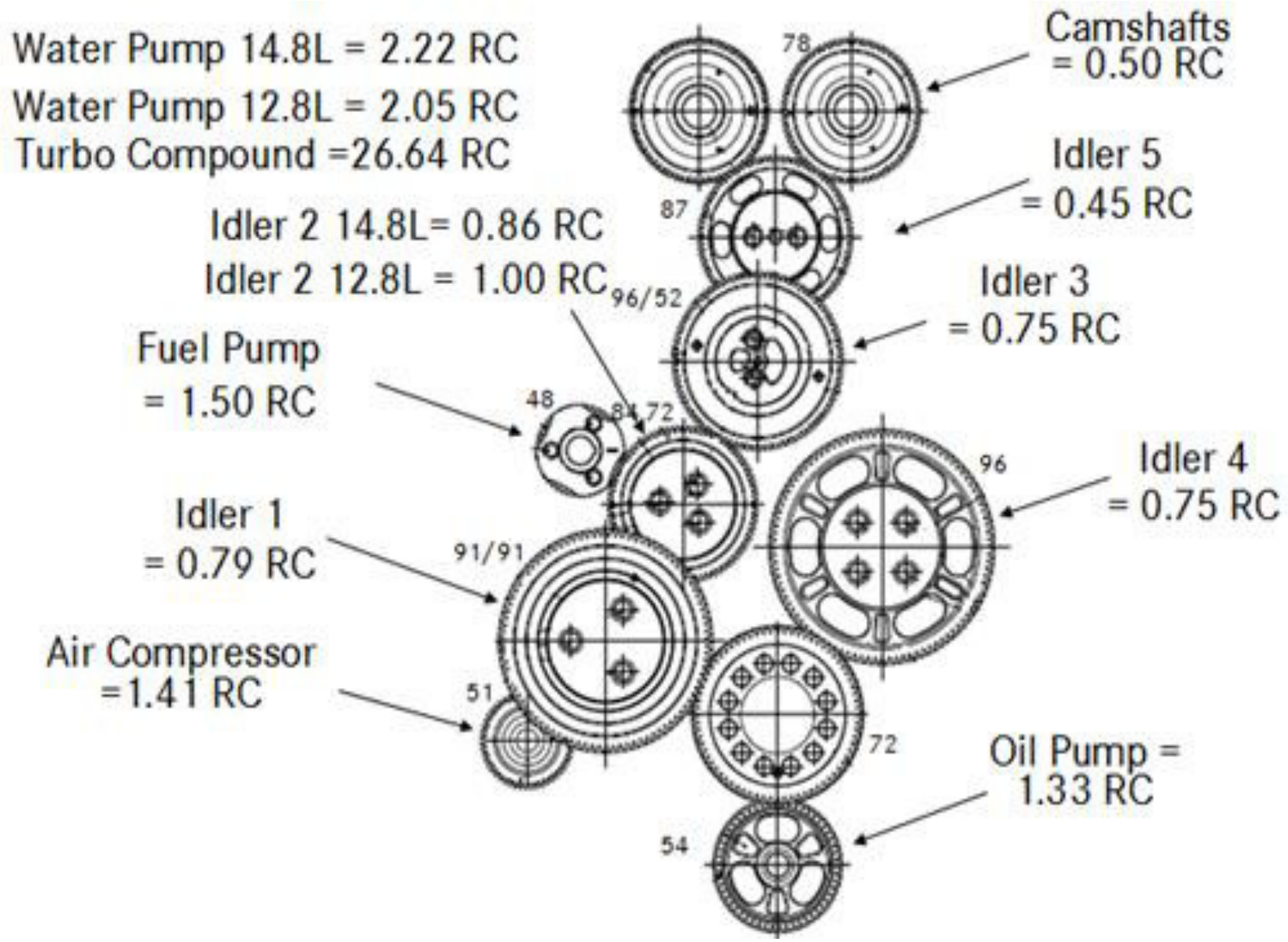


Fraction	Decimal Equivalent
1/16	0.0625
1/8	0.1250
3/16	0.1875
1/4	0.2500
5/16	0.3125
3/8	0.3750
7/16	0.4375
1/2	0.5000
9/16	0.5625
5/8	0.6250
11/16	0.6875
3/4	0.7500
13/16	0.8125
7/8	0.8750
15/16	0.9375

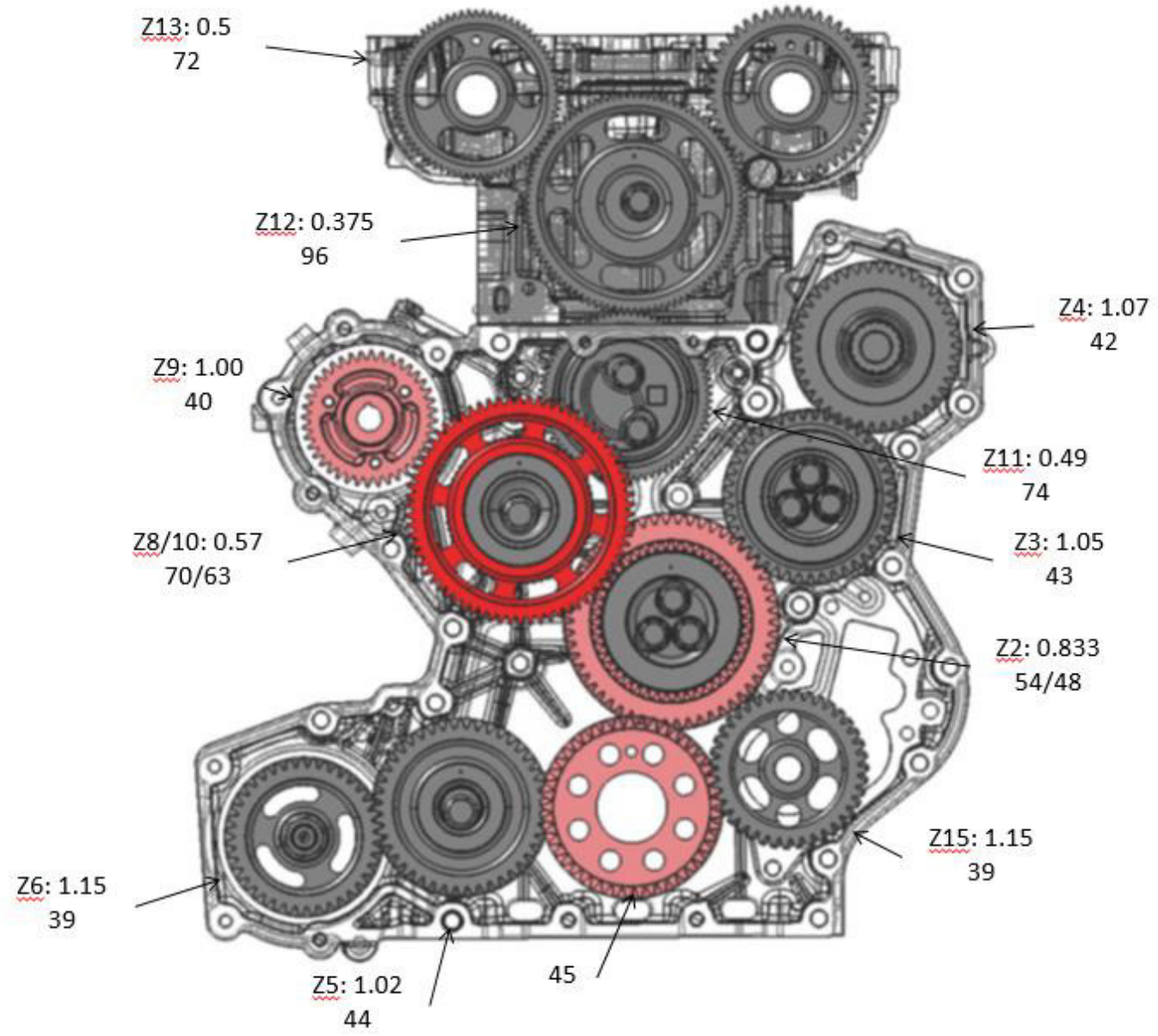
Engine Accessory Diagnostics



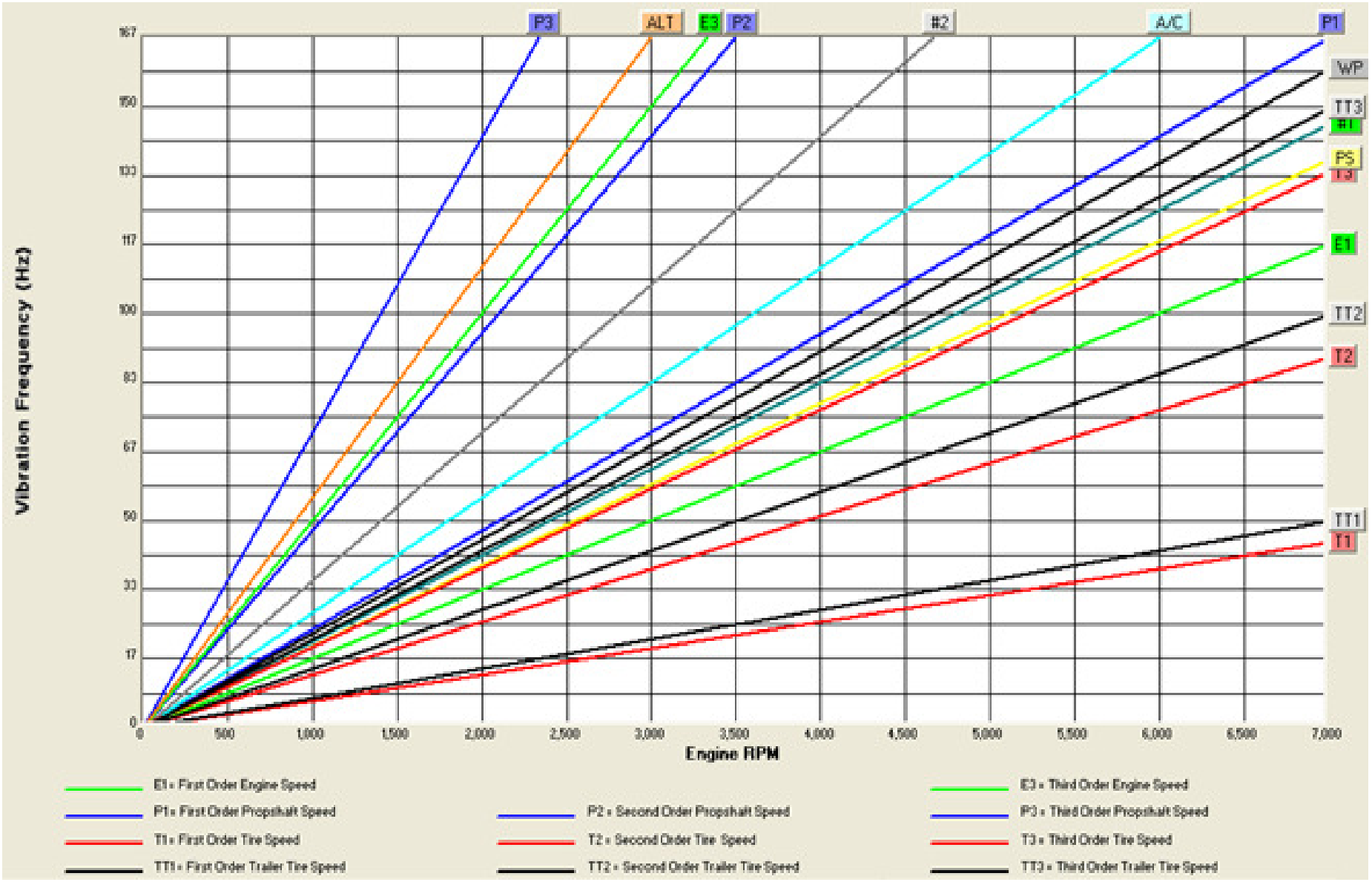
DD15/DD13 Gear Train Ratios



DD5/DD8 Gear Ratios



Sample Complete Vehicle Analysis Graph Vibrate 5.1 Software



GHG 17 and Potential Driver Feedback on Vibration

- Asymmetric Injection is an engine control strategy used to increase exhaust temperatures for ATS over-the-road regen functions on DD 13 and DD 15. It is not used for parked regens. In involves the biasing of fuel injection quantity towards the rear cylinder bank (4-6). The amount of fuel biasing, or “asymmetry” varies with speed and load, but primarily with load. It can be as little as none, so equivalent injection across all cylinders. It can be as much as full, so double fuel on rear bank (4-6) and no fuel on front bank (1-3). A difference in sound will be perceived when injection is heavily biased toward the rear cylinders, but is not an indication of issues. Customer education will be necessary. An increase in vibrations at the 1.5 order of engine speed can be expected.

Diagnostic Assistance and Service Related Bulletins

- **Some Type of Vibration Analyzer (EVA)** is a required tool for the technician to analyze vehicle vibrations.
- **TSN 31-01 Rev. A** is for Western Star and labeled as a harsh rid but is has information that addresses frame beaming.
- **SB 01-78** is for checking Engine Vibration complaints.
- **SB 32-31** rough Ride Diagnosis and measuring RF V

Vibration Training Question # 1

VIN# N92199 Rear Axle ratio 3.42

Transmission Top Gear Ratio .73

Complaint: Vibration felt in drivers seat 55mph to 70 mph.

Speed	RPMs	Hz	G's	Sensor Location
55	1200	8	.07	seat base
60	1500	10	.10	seat base
65	1800	12	.10	seat base
70	2100	14	.10	seat base

What is the conclusion?

List the steps to diagnose this condition.

Vibration Training Question # 2

VIN# BK0156 Rear Axle Ratio 3.90

Transmission Top Gear Ratio .74

Complaint: Vehicle vibrates at speed range 45mph to 70mph.

Speed	RPMs	Hz	G's	Sensor Location
45	1350	8	.10	seat base
50	1150	8	.14	seat base
55	1300	8	.24	seat base
60	1450	8	.27	seat base
65	1500	8	.41	seat base
68	1515	8	.31	seat base

What is the Conclusion?

What is the next step ?

Vibration Training Question # 3

VIN# BE2258 Rear Axle Ratio 3.90

Transmission Top Gear Ratio .74

Complaint: Severe Vibration felt in cab from 55 mph to 70 mph.

Speed	RPMs	Hz	G's	Sensor Location
55	1400	32	.16	seat base
65	1600	36	.18	seat base
70	1750	40	.22	seat base

What is the Conclusion?

List the steps to diagnose this condition.

Vibration Training Question # 4

VIN# BJ7900 Rear Axle Ratio 4.30

Transmission Top Gear Ratio .73

Complaint: Vehicle Vibrates 55 to 65 mph.

Speed	RPM's	Hz	G's	Sensor Location
56	1500	70	.20	seat base
60	1600	74	.19	seat base
65	1750	80	.22	seat base

What is the Conclusion?

List the steps to diagnose this condition.

Vibration Training Question # 5

VIN# BJ6438 Rear Axle Ratio 4.89

Transmission Top Gear Ratio .65

Complaint: Vehicle Vibrates 45mph to 70mph.

Speed	RPMs	Hz	G's	Sensor Location
45	1200	6	.03	seat base
59	1600	8	.03	seat base
68	1850	20	.03	seat base

What is the conclusion?

List the steps to further Diagnose this condition.

Vibration Training Question # 6

VIN# Z80340 Rear Axle Ratio 4.30

Transmission Top Gear ratio .67

Complaint: Vehicle vibrates 50 to 60 mph.

Speed	RPM's	Hz	G's	Sensor Location
53	1300	32	.38	Frame Rail
57	1400	8	.18	Frame Rail
61	1500	10	.20	Frame Rail
65	1600	40	.30	Frame Rail

What is the Conclusion?

List the steps to diagnose this condition.

Evaluating Vibration Data

➢ Train your eye to look at:

- **Sensor location:** sensor readings not in cab have no pertinence towards complaint validation. However the sensor can be moved to isolate the source of vibration and can used to determine if a mount is being properly isolated.

- **High "G" readings:** particularly the ones over .07g and a Hz of 20Hz or below.

- **Frequency increase with speed increase:** natural component frequencies mathematically increase with vehicle speed. Particularly in the case of wheel ends, this knowledge will help you determine if you reading is frame beaming.

Component Speed Calculations

$$\text{Tire Speed} = \frac{\text{Engine RPM}}{\text{Trans Ratio} \times \text{Axle Ratio}}$$

$$\text{Driveshaft Speed} = \frac{\text{Engine RPM}}{\text{Trans Ratio}}$$

$$\text{Miles Per Hour} = \frac{\text{Engine RPM} \times 60}{\text{Trans Ratio} \times \text{Axle Ratio} \times \text{TRPM}}$$

$$\text{Engine RPM} = \frac{\text{MPH} \times \text{Trans Ratio} \times \text{Axle Ratio} \times \text{TRPM}}{60}$$

Component Speed Calculations

$$\text{Axle Ratio} = \frac{\text{RPM x 60}}{\text{TRPM x MPH}}$$

$$\text{Hz} = \frac{\text{RPM}}{60}$$

$$\text{RPM} = \text{Hz x 60}$$

Component Speed Calculations

➢ Tire-Revolution-Per-Mile Calculation

- To calculate tire-revolution-per-mile (TRPM): Lay a straightedge across the top of both drive tires. With a tape, measure the distance from the bottom of the straightedge to the ground in inches. Divide that number into 20168. This will give you the tire-revolutions-per- mile.

- If the vehicle is equipped with new tires, you can subtract ½ of the tread depth from your measurement and you will have an accurate TRPM throughout the wear life of the tire