Lesson Objectives

1. Introduce the concepts relating to Noise, Vibration and Harshness (NVH).
2. Define NVH terminology.
3. Develop the background necessary for NVH diagnosis and the use of the NVH Analyzer.
4. Introduce the concepts of the transmission of vibration and sound.
5. Introduce the concepts of preventing vibration and noise.
6. Develop skills in associating NVH symptoms to the:
   - Sensation
   - Frequency range
   - Operating conditions
   - Causes
   - Vibrating system
**Introduction**  

Noise and vibration normally exist in the operation of a vehicle. When they become unpleasant to the senses they may be regarded as problems by the customer. NVH (Noise, Vibration and Harshness) is the term used when discussing these conditions.

**Noise, Vibration and Harshness**  

Fig. 1-1

We experience vibration by our senses of touch and vision. We experience sounds by our sense of hearing. People can perceive the same noise and vibration differently. To some it may be annoying, to others merely unpleasant while others may not notice it until it is pointed out.

**Sensing Vibrations**  

Fig. 1-2
The NVH condition that is a concern does not have to be the strongest vibration or the loudest noise. It could be one that was not there before or one that is not acceptable to the customer. Therefore it is critical that we **verify the customer's complaint.**

For example:

Tire pattern noise from a vehicle with block or lug pattern tires could be acceptable to the owner of a 4 X 4. A complaint on the same vehicle could be much more subtle, caused by a driveline problem.

Because we sense vibration and sound using different senses, we tend to discuss them separately. But **vibration and sound are essentially identical.**

**A sound is a vibration (pressure fluctuation) of the air.**

Vibrations and sounds are both expressed as **waves per second** called **Hertz (Hz),** discussed in detail later.

- Vibrations that are felt are under 200Hz
- Vibrations between 20Hz - 20,000Hz are audible by humans
- Vibrations over 20,000Hz are ultrasonic and not audible by humans
Section 1

4 LEXUS Technical Training

Frequency Ranges of Vibration and Sound

Fig. 1-3

- Vibrations Only 20 Hz or less
- Audible Range
- Sound Only 200 to 20k Hz
Audible Range

Fig. 1-4

Maximum Auditory Frequency

Pneumatic
Jack Hammer

Impact
Wrench

Washing
Machine

Audible Range

Electric
Cooling Fan

Speech

Music

Grinder

AMPLITUDE
(LEVEL)

Minimum Auditory Frequency

FREQUENCY Hz

Characteristics of vibration

Introduction

NVH phenomena can be a difficult concept to grasp. It is similar to the concept of electricity, we only experience the results in both cases. We cannot see it as easily as a broken or worn component.

For example:

The light from a light bulb is not electricity, but the result of electricity. The movement felt by a customer is not the source of the vibration. It occurs as a result of a condition such as an imbalance.

Vibrations, like electricity, have **basic characteristics which are always present**. Understanding these characteristics will allow a technician to predict the source of a vibration.
**Vibration**  The up and down movement of the weight and spring model shown below represents a vibration. This movement or vibration exists as a result of a weight suspended by a spring and an external force.

The factors that determine movement or vibration are:

- The size of the spring
- The size of the weight
- The amount of force pulling on the weight starting it in motion

The model consisting of the suspended weight and spring is called the **vibrating system**.

Anything that vibrates is a vibrating system including:

- A string on a musical instrument
- A bell
- A tuning fork

The weight and spring model or vibrating system can be started into motion by pulling on the weight. This action is known as the **vibrating** force. A vibrating force is the external force or energy putting a vibrating system into motion.

Plucking a string on a guitar or striking a bell or tuning fork are the vibrating forces that cause these vibrating systems to vibrate and make noise.
Vibration

Continued

For example:

A vibrating system in a vehicle is the suspension.

- The spring on the vehicle is similar to the spring on the model.
- The weight of the vehicle is similar to the weight on the model.
- Bumps in the road are the external or vibrating forces that start the vehicle into motion.

If you remove the shock absorbers a vehicle will move or vibrate in a similar manner to the weight and spring model.

A technician can bounce a corner of a vehicle and watch the motion to check for bad shocks. If the shocks are good they will **dampen** the motion quickly.
Oscillation is another term used to describe the movement of a vibration. When something oscillates it moves back and forth around a common point.
Cycle  If a constant vibration or movement in any vibrating system is plotted over time a pattern appears. This pattern consists of the repetitive movement of the weight.

Tracing this pattern from the resting position through each extreme and back to the resting position will produce one cycle.

Cycle comes from the word circle. The travel of the weight on either side of the resting position, is half of a circle.

The distance the weight travels from either side of the resting position will be the same as long as the vibrating force remains constant.

\[ A = B \]
For example:

Another example of frequency or cycle is rotating a crankshaft 360° starting at TDC. This movement is one revolution. We measure the speed of an engine by counting these revolutions in one minute (RPM).

Rotating the crankshaft from TDC through 360° and back to TDC is also one cycle of the crankshaft. As defined above the crankshaft starts at a specific point, travels in a circle and returns to the same point.

Plotting the movement of a crankshaft over time will result in a similar pattern to the movement of the spring and weight model. (Fig. 1-7)
**Frequency**  The number of *cycles in one second* is the frequency of the vibration.

The unit for frequency is **Hertz (Hz)**.

The number of cycles in a second or the frequency (Hz) can be changed by changing the vibrating system. If the strength of the spring is changed or the size of the weight is changed the frequency will change. (All other aspects of the vibrating system unchanged)

- A stronger spring will increase the frequency (Hz)
  - More tension will move the weight at a faster speed
- A weaker spring will decrease the frequency (Hz)
  - Less tension will move the weight at a slower speed
- A heavier weight will decrease the frequency (Hz)
  - More weight will increase the resistance on the spring and it will move at a slower speed
- A lighter weight will increase the frequency (Hz)
  - Less weight will decrease the resistance on the spring and it will move at a faster speed
Vibration Characteristics

Fig. 1-10

WEAKER SPRING  STRONGER SPRING  HEAVY WEIGHT  LIGHT WEIGHT

Sensors Signal

Fig. 1-11

Ne SIGNAL (Crankshaft RPM)

G SIGNAL (Crankshaft Position)

WHEEL SPEED SENSORS FOR ABS
**Calculating Component Frequency**

Frequency can also be expressed in **Revolutions Per Minute (RPM)**. **RPM** is a common unit for rotating components in the automotive field. RPM can be converted to **Cycles Per Second (CPS) or Hertz (Hz)** by dividing RPM by 60. There are 60 seconds in one minute.

\[
\text{RPM} \div 60 \text{ sec} = \text{CPS or Hz}
\]

If a crankshaft is rotating at 3000 RPM then it has a frequency (Hz) of 50 CPS or 50 Hz.

\[
3000 \text{ RPM} \div 60 \text{ sec} = 50 \text{ Hz}
\]

This formula can also assist the technician in identifying the source of a vibration in a vehicle. If the frequency is known then the RPM can be calculated.

\[
\text{Hz} \times 60 \text{ sec} = \text{RPM}
\]

A technician can now determine what component is turning at a calculated RPM, during the vehicle conditions at which the complaint occurs.

For example:

- Engine RPM can be read from a tachometer **3000 RPM**
- Driveline RPM is the same as engine RPM in fourth gear with a 1:1 gear ratio. (Manual Transmission)

\[
\text{Engine @ 3000 RPM} \div 1 = 3000 \text{ RPM drivetrain speed}
\]

- 3000 RPM = 50 Hz (engine speed and driveshaft speed).

If the gear ratio is other than 1:1, the engine RPM divided by the ratio equals the driveline RPM. (5th gear, W58 trans.)

\[
\text{Engine @ 3000 RPM} \div 0.783 = 3831.42 \text{ RPM driveshaft speed}
\]

- 3831.42 RPM = 63.85 Hz (driveline speed)
- Wheel RPM is calculated by dividing the RPM of the driveline by the gear ratio of the differential. (’93 Supra 2JZ-GE)

\[
\text{Driveline @ 3831.42 RPM} \div 4.272 = 896.87 \text{ RPM wheel speed}
\]

- 896.87 RPM = 14.95 Hz (wheel speed)

The frequency (Hz) of the vibration or sound can be determined with the use of test equipment. A **vibration analyzer** is able to display the vibrations in a vehicle. An abnormal vibration can be associated with a specific frequency from the display.

For example:

The engine could be determined as the source of a measured 50 Hz vibration with the crankshaft turning at 3000 RPM.
50 Hz x 60 sec = 3000 RPM
Amplitude

The amount of vertical movement of the spring and weight (vibrating system) is the amplitude of the vibration. The amplitude is determined by the external force or energy applied to the vibrating system.

Amplitude is the size of the wave and is measured two ways.

- Total amplitude from peak to peak (A)
- Half amplitude from resting position to the peak (B)

The higher the amplitude, the more noticeable the condition.

Vibration Measurement

A vibration is measured in two ways:

- Frequency (Hz)
- Amplitude (dBg)

Frequency is a function of the system design and amplitude is the result of the energy on the system.

Both of these features can be measured with a vibration analyzer which senses, processes and displays the vibrations in a vehicle. The information from a vibration analyzer can help the technician determine the:

- Frequency of vibration (Hz) - which can indicate the source
• Amount of energy/amplitude(dBg) - which indicates the level of the vibration the customer feels
The vibration analyzer recommended by Toyota is a feature of the **Toyota Diagnostic Tool Set**. The NVH portion of the tool includes:

- An **accelerometer** to sense the vibration
- A **data link** to input RPM and MPH
- A **program card** specific to the NVH function

![NVH Analyzer](Fig. 1-13)
The tool will display the vibrations occurring in a vehicle and aid the technician in diagnosing an NVH complaint.

The unit of measurement used by the NVH Analyzer for:
- **Sound level** is the dB (decibel)
- **Vibration level (amplitude)** is dBg (g force related to gravity)

The dB is the unit of measurement related to the level or intensity of what we hear. It is a mathematical calculation (logarithm) of a vibrating force that produces a sound. It is useful to associate the level or amplitude of the vibration to the **level sensed by the customer**.

The dBg is the unit that is related to the level or intensity of what we feel. When measuring the level or amplitude of a vibration without sound the unit g is added to associate the force of the vibration to gravity. This is similar to measuring the weight of an object which is also a function of gravity.

Level or amplitude becomes important in determining the success of the repairs performed. If the amplitude of a vibration or sound is measured before and after a repair then a comparison can be made. The results are much more objective than using the senses of touch and hearing.

The graph on the left shows the actual sound level from various sources.
- The graph on the right shows the customer perceived sound level from the same sources and easier to read.

**Natural Frequency**

All vibrating systems have a **specific vibrating frequency** unique to that system design. This frequency is called the **natural frequency**.

If any of the characteristics of the vibrating system change then the **natural frequency changes**. (as stated in the section on frequency)

If the **external force** on a vibrating system is changed then the **amplitude changes** but the **natural frequency remains the same**.

A vibration or sound that develops in a vehicle may be caused by a change in the status of a component like a bad seal in a strut. The natural frequency of the suspension system is changed due to the loss of dampening in the strut. The suspension system will now vibrate noticeably over the same road conditions which had not previously caused a customer complaint.

In this example the technician can resolve the customer complaint by restoring the suspension system to the original condition and natural frequency.
Resonance occurs when the **vibrating force** (external force) on a vibrating system is moving at the **same frequency** (Hz) as the **natural frequency** of that vibrating system. Fig. 1-15 shows the wave form of the natural frequency of the system and the wave of the vibrating force at the same frequency. The resulting wave that occurs is at the same frequency but with much greater amplitude.

This is a significant phenomenon in a vehicle because the increased level is sensed by the customer and perceived to be a problem.

The frequency (Hz) at which this occurs is the “**resonance point**”.

The amplitude (dBg) of the vibrating system increases dramatically when the resonance point is reached.
In the above example with the suspension system vibration (caused by the leaking strut), the vibration the customer feels is amplified when:

- The new natural frequency of the suspension system and the frequency of the tire on a rough road are the same
- When the frequencies are the same they resonate increasing the level or amplitude

When the leaking strut is repaired the original natural frequency of the suspension system is restored. The suspension system frequency will not be the same as or resonate with the frequency of the tire on a rough road during normal operating conditions.

Fig. 1-16 shows that moving the vibrating force frequency to either side of the resonance point will **lower the amplitude**.

If the vibrating force cannot be changed then changing the natural frequency of the vibrating system will also lower the amplitude.

The shock absorber, in the suspension system example, changes the natural frequency of the suspension system. The technique is called **dampening**. The shocks change the resonance point of the system and reduce the vibration felt by the customer.
Varying the Frequency to Modify Resonance

Fig. 1-18

Vibrating Force Below the Natural Frequency

Vibrating Force

Vibration

Vibrating Force

Vibration

Vibrating Force Equal to the Natural Frequency

Natural Frequency

Resonant Vibration

Vibrating Force

Vibration

Vibrating Force Above the Natural Frequency

Vibration
Another example of resonance is an unbalanced tire as it reacts with a suspension system. The vibration is usually more noticeable at a specific speed range. This is the point when the vibrating force (unbalanced tire) and the natural frequency of the suspension system resonate. The customer feels a strong vibration when this occurs due to the significant increase in the vibration level (amplitude).

In this case, balancing the tire will return the system back to the original design and move the resonance point out of the normal operating range. The customer will no longer feel a vibration.
Resonance is not always a negative condition. Engineers use the phenomenon of resonance in the design of a number of products including the knock sensor. The knock sensor is monitored by the ECM to modify timing.

The vibration generated by a detonation or a knock is transmitted through the cylinder block to the knock sensor. The natural frequency of the piezoelectric element in the sensor is designed to match the frequency of the vibration caused by the knock. When the knock occurs, its frequency and the natural frequency of the sensor are the same, and they resonate.

The amplitude of the vibration sensed increases sharply due to the resonance of the element.

At the same time the voltage generated by the piezoelectric element in the sensor increases in proportion with the amplitude. The computer monitors the voltage and makes corrections to engine timing to eliminate the detonation or knock.

The vibrating force, in this case, is the explosive force created by an abnormal combustion of the fuel.
Transmission of Vibrations and Sounds

Vibrations and sounds are transmitted the same way. There has to be a:

- Vibrating force
- Resonating system
- Transmission system (path)
- Vibrating element (vibration)
- Vibration of air (sound)

Transmission of Vibrations and Sounds

Fig. 1-21
Examples of **vibrating forces** in automobiles are:
- Combustion (engine firing)
- Tires contacting a rough road
- Imbalance or run-out of a rotating component
- Fluctuation of friction surfaces

A **Resonance System** is any component on the vehicle that resonates when it receives a vibrating force. All components will resonate if the vibrating force matches the natural frequency.

The most common examples are:
- Tires resonate when vibrated by the road
- Suspension systems will resonate with an out of balance tire
- An exhaust system will resonate when vibrated by the engine

The **Transmission System** is the path in the vehicle that carries the vibration from the resonance system to the vibrator (sound generator).

Examples of a transmission system or path are the:
- Exhaust system
- Engine mounts

These components carry engine vibrations through the vehicle.

The following are examples of methods used to minimize the level of vibration felt by the customer through modifying the transmission path:
- Rubber O ring exhaust hangers
- Liquid filled mounts

The **Vibrator** (sound generator) is the component that generates the vibration or sound that the customer senses.

Examples of a vibrator (sound generator) are:
- Body
- Steering wheel
- Seat
- Shifter
- Mirror

**Asphalt sheeting** on a body panel is an example of a **modification** to the vibrator to insulate the passenger compartment from a vibration or sound.
Examples of Transmission Paths

Fig. 1-22

Preventing Vibrations and Sounds
Diagnosing and repairing NVH complaints can be easily understood by looking at the vibrating force and the transmission of vibrations and sounds.

Transmission of Sound
Fig. 1-23
Preventing Vibrations and Sounds

Continued

The vibrating force is usually the first area a technician considers in troubleshooting. This is especially true if something has changed with the source such as an imbalance, run-out or a worn component.

In some cases the vibrating force may not have changed or may not be the easiest area to repair. Changing any part of the vibrating system will also change the vibration or sound the customer senses.

For example:

A vibration that is a result of an exhaust system that is in contact with the body.

- Vibrating force is the engine
- Resonating system is the exhaust system
- Transmission system is the contact of the exhaust to the body
- Vibrating element is the body panels

The repair would involve eliminating the contact of the exhaust system to the body (transmission path). This is the most likely area where the vehicle condition has changed causing the complaint. Careful examination of the system should identify the cause of the
grounded exhaust. The repair may involve a hanger or replacement of bent exhaust components.

**Dampers**  
Engineers can modify a vibrating system during the design of a vehicle with the use of **mass or dynamic dampers**.

A **mass damper** is an extra weight attached to a resonance system to **lower** its natural frequency. It does two things:
- Moves the vibration or noise outside the normal operating speed range
- Reduces the vibration level or sound pressure level
A dynamic damper consists of springs (rubber) and a plumb weight that are fitted to a resonance system. When a dynamic damper is added, a large vibration having a single natural frequency is divided into two vibrations having two smaller natural frequencies.

The vibration level and sound pressure level are reduced as a result.
**Dynamic Damper**

Fig. 1-27

**Dynamic Damper Theory**

Fig. 1-28

---

**Additional NVH Phenomena**

Phase is the lateral shift of a wave as it relates to another wave. For phase to have an impact on the vibrations sensed in a vehicle, there has to be **two vibrations** of the same frequency. The lateral shift
determines how the high and low peaks of the waves line up and create the conditions, such as beating, explained below.

*Phase*

The same sounds with opposed phases will cancel each other.

Fig. 1-29

The Sound Will Disappear
Beating or phasing occurs when two similar vibrations or sounds with slightly different frequencies exist in the same area or vehicle.

Over a period of time the phase of the two waves will change due to the slight difference in frequencies. At times:

- The two higher points overlap and create an even higher peak which raises the level or amplitude.
- The two low points overlap to make an even lower point which lowers the level or amplitude.

This change in intensity or amplitude occurs in a repetitive manner at a constant vehicle speed as the phase of the wave changes over time.

The resulting wave creates a sound called beating, which is associated with a vehicle having more than one tire out of balance. Tires are not always the same size and will rotate at slightly different speeds (Hz).

This condition can be corrected by eliminating either one of the vibrations. If one tire is balanced then the beating noise will be eliminated leaving the constant vibration from the remaining out of balanced tire. Correcting the second tire will return the vehicle to its original condition and ensure customer satisfaction.

You may have noticed a beating condition in a twin engine boat or airplane. If the engines are out of “sync” there is a strong cyclic vibration and sound. When the pilot adjusts the RPM on the engines, the beating vibration and cyclic sound goes away.
Growl/Beat Wave Form
Fig. 1-30

VIBRATION

PERCEIVED BY CUSTOMER

Increases

Cancels

$500\text{Hz}$

$504\text{Hz}$

$+$

4 cycles/sec

GROWL (BEAT)
Order  A single vibrating force may generate more than one vibration.

For example:

An out of balance tire can develop multiple vibrations due to the distortion of the tire as it rotates. This is a characteristic of radial tires. The tire is no longer round and bumps rise on the tire causing the additional vibrations.

The distortion of the tire is caused by centrifugal force as the tire rotates. Centrifugal force is similar to swinging a yo-yo in a circle. The faster you swing it, the more the pull. This pulling force is what causes the tire to change shape.

As the tire rotates, the heavy spot on the tire causes an up and down motion as it contacts the road. This will induce a vibration into the suspension and steering system which will be felt by the driver. The centrifugal force of the rotating heavy spot also contributes to the up and down movement.
The vibration caused by the heavy spot is a first order vibration. It occurs once every revolution of the tire.

A first order vibration can be the largest amplitude vibration of the vibrations caused by the imbalance.

Due to centrifugal force and the heavy spot, the tire changes shape raising additional high spots on the tire. As these spots contact the road they also cause an up and down motion that is induced into the suspension and steering systems.

This second vibration is caused by a second bump in the tire as a result of the change in shape. It is usually smaller in amplitude than the first order vibration. This is called the second order or second component vibration.

Because there are two vibrations in one rotation of the tire, the second order vibration will be approximately twice the frequency of the first order and a spike on a frequency analyzer will appear at that frequency.

The third vibration is caused by a third bump as a result of the change in shape. It is generally smaller in amplitude than the second order vibration though there are some applications and speeds where it may be greater in amplitude than a first order vibration. This vibration is called the third order or tertiary component vibration. It will appear as a spike on a frequency analyzer at three times the first order vibration due to the three vibrations in one revolution of the tire.
**Multiple Order Tire Vibrations**

Fig. 1-32
NVH in Automobiles

There are three major sources of vibration in an operating vehicle.
- Engine/Accessories
- Driveline
- Wheels and tires

Each of these sources usually rotate at different speeds or frequencies in an operating vehicle. This is useful in diagnosis. A component generating a vibration can be associated with one of the source groups if the frequency of the vibration can be determined (discussed in Section 2).

For example:

A V6 4Runner, AT, with 31 inch tires traveling at 50 MPH, in OD, will have:
- An engine speed of 2050 RPM/34.1 Hz
- A driveline speed of 48.5 Hz
- Wheel speed of 10 Hz

The different speeds of these component groups above, are determined by the gear ratios of the transmission and differential. Therefore, the speeds will be different for vehicles with different tire sizes, transmissions and differentials.
Driveline vibrations are caused by:

- Imbalance
- Runout
- U-joint condition

The force from a driveline imbalance or runout will usually cause a first order vibration because it occurs once per revolution of the shaft.

Driveline concerns relating to U-joints are caused by:

- Phase
- Joint condition i.e.: tight/loose
- Working angle/inclination

As a U-joint rotates it accelerates and decelerates **twice per revolution**. Therefore conditions relating to U-joints will generate second order vibrations.
Engines will also generate multiple vibrations. A first order engine vibration is associated with the **rotational force or torque**. It is usually associated with imbalance or runout conditions such as in a flywheel, torque converter or harmonic balancer.

Engine firing or combustion will produce **vibrations relative to the number of cylinders** in the engine. The order will be **one half the number of cylinders**. A four-stroke engine requires two complete revolutions of the crankshaft to fire all the cylinders.

For example:

A four cylinder engine fires cylinders 1 and 3 in the first revolution and 2 and 4 in the second revolution. Two pulses per revolution are generated which is a second order vibration. (Second order of crankshaft frequency)
A six cylinder engine fires three cylinders in the first revolution and three in the second causing three pulses per revolution or a third order vibration.

<table>
<thead>
<tr>
<th>RPM</th>
<th>Hz</th>
<th>4CYL 2nd Order</th>
<th>6CYL 3rd Order</th>
<th>8CYL 4th Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>8.3</td>
<td>16.6</td>
<td>24.9</td>
<td>33.2</td>
</tr>
<tr>
<td>750</td>
<td>12.5</td>
<td>25</td>
<td>37.5</td>
<td>50</td>
</tr>
<tr>
<td>1000</td>
<td>16.6</td>
<td>33.3</td>
<td>49.8</td>
<td>66.4</td>
</tr>
<tr>
<td>1500</td>
<td>25</td>
<td>50</td>
<td>75</td>
<td>100</td>
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<td>2000</td>
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<td>66.6</td>
<td>99.9</td>
<td>133.2</td>
</tr>
<tr>
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<td>83.2</td>
<td>124.8</td>
<td>166.4</td>
</tr>
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<td>3000</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>200</td>
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<tr>
<td>3500</td>
<td>58.3</td>
<td>110.6</td>
<td>174.9</td>
<td>233.2</td>
</tr>
<tr>
<td>4000</td>
<td>66.6</td>
<td>132.4</td>
<td>199.8</td>
<td>266.4</td>
</tr>
</tbody>
</table>

**Order Continued**

**Firing Frequency**

Fig. 1-35

Fourth, fifth and greater order vibrations can exist but the first three are most common, noticeable and useful for diagnosis. If the technician identifies and repairs any of the first three vibrations the remaining vibrations will also be reduced.

The NVH Analyzer will display all of the most common vibrations in an operating vehicle. It also uses arrows to point to various order vibrations of the engine, driveline and wheels. The arrows aid in the diagnosis of complaint vibrations by pointing to the frequencies associated with these sources.

If a technician notes a large spike over one of the arrows, then a pinpoint diagnosis can begin in the area indicated by the arrow.
Harshness

Harshness is the condition a customer senses when a vehicle contacts a single impact such as road irregularities, railroad tracks or speed bumps.

The level of impact that the customer senses depends on the type of suspension used on a vehicle. A sports car suspension system is designed for handling and to give the driver a good “feel of the road”. A luxury vehicle is designed to provide the most comfortable ride possible, insulating the driver from unpleasant sensations.

A harshness complaint is relative to the type of vehicle involved and should be compared to other vehicles of the same type.

<table>
<thead>
<tr>
<th>Transmission Path of Harshness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig. 1-36</td>
</tr>
</tbody>
</table>

A vibration analyzer will not be the primary tool used to diagnose a harshness complaint because the incident is momentary and difficult to isolate. In addition, the source causing the disturbance is already known and cannot be controlled. What has usually changed, causing the concern, is the transmission system or path.

A good visual inspection starting at the location in the vehicle where the symptom seems to originate, will usually identify the component that has changed or deteriorated.
NVH in Automobiles
Continued

Shifting gears will also change engine speed at the same MPH. This will be useful for diagnosis during a road test where modifying the symptoms can help isolate the source (discussed in Section 2).

Section 2 provides the diagnostic procedures to classify the symptom and identify one of the three major source groups generating the condition.

Section 3 deals with pinpoint diagnostic procedures to isolate the condition causing the vibration or noise.

In addition to a frequency analyzer, our everyday experience with common vibrations and noises can be helpful in diagnosis. As a technician you have become accustomed to how many vibrations feel. This experience can be applied to troubleshooting a vibration in a vehicle.

If a symptom feels like one of the examples in fig. 1-38 then the frequency is the same as noted. This frequency or speed can now be associated with a component group and pinpoint diagnosis can be conducted in that component area.

For example:

A vehicle traveling between 40-50 MPH has a vibration that feels like a spinning washing machine (10-15 Hz). It is likely to have a wheel condition causing the vibration. At 40-50 MPH the wheel frequency is approximately 10-15Hz depending on the tire/wheel diameter.
Example Vibrations

Fig. 1-38

- Waves: 1 – 3 Hz
- Washing Machine: 10 – 15 Hz
- Impact: 20 – 30 Hz
- Grinder: 60 Hz
- Electric Cooling Fan: 120 – 140 Hz
In order to help standardize and define the terms used to describe NVH symptoms, the following chart has been developed as a reference. It will be used extensively throughout this course.

The chart covers the common NVH conditions that occur in an operating vehicle. It includes:

- A description of the NVH condition
  - What the customer senses
  - Under what circumstances the NVH condition occurs
- Associated frequency range
- Vibrating force
- Vibrating system of the vibration or sound
- Other characteristics specific to the condition

**Common NVH Symptoms**
<table>
<thead>
<tr>
<th>SYMPTOM</th>
<th>SENSATION</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Shake</td>
<td>1. A major vertical and/or lateral vibration of the body, seats and steering wheel. 2. Frequency 10-30 Hz</td>
<td>1. The vibration occurs at a specific speed when driving at a moderate or high speed.</td>
</tr>
<tr>
<td>Steering Flutter and Shimmy</td>
<td>1. Rotational steering wheel vibration 2. Shimmy has a relatively low frequency 5-15 Hz 3. Flutter is a higher frequency than shimmy</td>
<td>1. Flutter vibration is usually constant and generated at a limited range of speed during moderate to high speed driving. 2. Shimmy is generated when driving over a rough road or when the brakes are applied. It occurs at a lower speed than flutter and increases with vehicle speed.</td>
</tr>
<tr>
<td>Accelerator pedal vibration</td>
<td>1. A vibration of a small amplitude, transmitted from the accelerator pedal to the driver’s foot. (it never vibrates along the stroke direction of the pedal). 2. Frequency 20-200 Hz (4cyl)</td>
<td>1. The vibration occurs at a high engine RPM 2. Vehicle speed has no impact on the vibration.</td>
</tr>
<tr>
<td>Shift lever vibration</td>
<td>1. A vibration of a small amplitude felt at the shift lever. 2. Frequency 100-200 Hz</td>
<td>1. The vibration occurs at a specific RPM at high engine speed.</td>
</tr>
<tr>
<td>Riding comfort</td>
<td>1. Refers to a slow swaying motion of the entire vehicle rather than a vibration. 2. It also refers to impacts from road irregularities being transmitted directly to the vehicle body. 3. Frequency 1-15 Hz</td>
<td>1. Generated when going over large bumps or dips in the road surface. 2. It is also generated when driving on irregular roads at a specific speed.</td>
</tr>
<tr>
<td>Harshness</td>
<td>1. A momentary heavy impact that resembles hitting the tire with a hammer. The vibration is felt in the steering wheel, seats, and floor. 2. It may be accompanied by a high-pitched impact sound. 3. Frequency 30-60 Hz</td>
<td>1. When going over road joints and gaps, the tire is deformed locally by an impact in the front-to-rear direction. 2. The impact is transmitted to the suspension system and body.</td>
</tr>
<tr>
<td>Road noise</td>
<td>1. A continuous blasting or rumbling sound at a constant pitch. It increases with the vehicle speed. 2. It also accompanies a very fine vibration seen on a vibration analyzer but difficult to feel. 3. Frequency ranges from 30-60 Hz and from 80-300 Hz</td>
<td>1. It changes with the surface of the road. The rougher the road, the more noise.</td>
</tr>
</tbody>
</table>
| Tire pattern noise | 1. A high pitched whining and roaring noise.  
2. The noise may change from roaring to whining as the vehicle speed increases.  
3. Frequency 100-5kHz | 1. Occurs on pavement with tires having blocked or lug pattern tread.  
2. The noise is more noticeable on flat, well paved roads. |
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<tr>
<th>CAUSES</th>
<th>VIBRATING SYSTEM</th>
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</table>
| Vibrating forces | 1. The vibrating force of the tire condition causes a vibration that is transmitted from the axle through the suspension system.  
2. The vibration will resonate with the body or engine which will cause the body to shake heavily.  
3. The vibration of the body is transmitted to the steering wheel and seat. | 1. The vertical and lateral shake may occur alternately every ten seconds, approximately. This is a result of a slight difference in the tire radius. A constant speed for at least ten seconds is required to attain this condition.  
2. Correcting the tire causing the vibration is usually the most effective method of resolving a body shake. |
| 1. Tire runout, imbalance or a uniformity problem  
2. Rotor or Drum Imbalance  
3. Axle hub eccentricity, runout or imbalance | Flutter | 1. In modern cars, flutter is more common than shimmy.  
2. Flutter and shimmy give similar sensations to the driver, but their mechanisms are not the same.  
3. Flutter is a forced vibration caused by the resonance of the vibrating force from the tires and the steering system.  
4. Shimmy is a direct vibration generated by the road irregularities or braking. |
| Shimmy | Flutter | 1. A vibrating force is generated by a tire imbalance.  
2. The vibration occurs around the steering axis causing the tire to vibrate to the left and right. This induces a vibration in the steering linkage.  
3. When the vehicle reaches a particular speed, the lateral vibration of the tire resonates with the steering system. The steering wheel vibrate along the rotationally as a result. | 1. Shimmy is similar to flutter except it is generated by road kick-back, tire deformation, or a vertical vibration from braking. The transmission path is the same as flutter. |
| 1. Kick-back from a rough road  
2. Tire - worn or low air pressure  
3. Steering linkage - loose, worn components  
3. Suspension - misalignment, lack of shock absorber dampingen | | |
| 1. Engine Vibration  
2. Cable  
3. Pedal | 1. The engine vibration causes the throttle linkage and cable to vibrate.  
2. The vibration is transmitted to the accelerator pedal. | |
| Vibrating forces | FR models | 1. The engine torque fluctuation or imbalance causes a bending vibration in the driveline. It can be amplified if there is also a propeller shaft condition like imbalance or joint angle.  
2. The vibration causes the extension housing to vibrate which in turn causes the shifter to vibrate. The vibration is more noticeable if the shifter is worn. | |
| 1. Engine torque fluctuation  
2. Imbalance of revolving or reciprocating engine components | FF models | 1. An engine imbalance causes a vibration in the shift lever. |
| Resonators | 1. Engine and transmission  
2. Driveline  
3. Shift lever | | |
| Vibrating forces | 1. Road irregularities  
2. Suspension - shock absorber dampening, spring modules of the suspension bushings or springs, rigidity of the stabilizer | 1. Road conditions cause the tires to move up and down inducing a vibration in the suspension system.  
2. The vibration in the suspension system causes the vehicle to bound and rebound which is felt as swaying by the passenger. |
| Resonators | 1. Tires - air pressure  
2. Suspension - shock absorber dampening, spring modules of the suspension bushings or springs, rigidity of the stabilizer | | |
| Vibrating force | 1. Harshness is greatly effected by tire characteristics. New low-aspect ratio tires have contributed to harshness concerns.  
2. Suspension system bushing design has been modified to include slits which help improve the ride. | |
| 1. Pavement joints, gaps, rail road tracks and speed bumps | 1. When driving on rough pavement, a fine vibration occurs in the tire which causes the tire to resonate and the vibration is amplified.  
2. The vibration is transmitted through the suspension system to a body panel that vibrates generating the noise. | 1. Suspension bushings are also designed to provide a good balance between road noise and handling. |
| Resonators | 1. Tire characteristics  
2. Suspension  
3. Body | | |
| Vibrating force | 1. Small road surface irregularities | | |
| Resonators | 1. Tires  
2. Suspension system  
3. Body | | |
| 1. Pumping of air by the tire tread. | 1. Air is trapped and compressed between the grooves of the tire and the road as it rotates.  
2. As the section of the tire leaves the ground, the compressed air is released and expands creating the sound. | 1. Pattern noise is greater if the area to trap air is larger such as truck tires. It is more noticeable if the grooves are perpendicular to the car’s body. |
<table>
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<tr>
<th>SYMPTOM</th>
<th>SENSATION</th>
<th>CONDITIONS</th>
</tr>
</thead>
</table>
| Body Booming noise | 1. A heavy droning sound that is oppressive to the ear and difficult to tell where it is coming from.  
                           2. Sometimes accompanies vibration in the body, seat and floor.  
                           3. The frequency increases as the vehicle speed increases. Frequency 30-100 Hz at low to medium speed and 100-200 Hz at high speed. (4cyl) | Booming noise is heard at a specific engine or vehicle speed. The range is very narrow.  
                           1. When affected by vehicle speed ± 6 MPH of peak speed  
                           2. When affected by the engine RPM ± 50 RPM of peak RPM |
| Body Beating noise | 1. The level of the sound changes cyclically.  
                           2. The cycle becomes shorter as the vibrating force speed increases.  
                           3. The cyclical sensation is more apparent when it occurs between 2-6 times per second. | 1. It occurs at a specific engine or vehicle speed.  
                           2. When two sounds having slightly different frequencies are present, the level of the combined sound changes cyclically and is felt as a beating noise.  
                           3. When the two high points of the wave coincide, the level of the sound is amplified. When the two low points line up, the level is much less noticeable. |
| Engine noise       | 1. A continuous sound heard in the passenger compartment that increases with engine RPM.  
                           2. Frequency 200-2kHz                                                     | 1. It is heard when the engine is running at a high speed or under load.    |
| Wind noise                                      | 1. The hissing or whistle of air heard near a window. |
|                                               | 2. Wind noise increases with vehicle speed and can change with wind direction. |
|                                               | 3. Frequency 500-5000 Hz |
|                                               | 1. It occurs at approximately 40-50 MPH with the windows shut. |
### VIBRATING SYSTEM

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<th>CAUSES</th>
<th>VIBRATING SYSTEM</th>
<th>REMARKS</th>
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</thead>
<tbody>
<tr>
<td>Vibrating force</td>
<td>Due to propeller shaft joint angles</td>
<td>1. The body booming noise can be engine related or vehicle speed related</td>
</tr>
<tr>
<td>1. Imbalance of rotating and reciprocating engine components, torque fluctuation 4cyl twice per revolution, 2nd order/secondary engine component 6cyl three times per revolution, 3rd order/tertiary engine component</td>
<td>2. A constant speed is necessary to allow the beating noise to cycle.</td>
<td></td>
</tr>
<tr>
<td>2. Torque fluctuation due to propeller shaft joint angle twice per revolution, 2nd order/secondary driveline component</td>
<td>3. Due to the fact that a beating noise requires two vibrations, if one is eliminated the beating noise will stop leaving the remaining vibration.</td>
<td></td>
</tr>
<tr>
<td>3. Propeller shaft imbalance once per revolution, 1st order/primary driveline component</td>
<td>1. The body booming noise can be engine related or vehicle speed related</td>
<td></td>
</tr>
<tr>
<td>4. Clutch assembly imbalance</td>
<td>2. Check to see if the condition exists when the engine reaches a specific RPM or if it occurs while coasting which indicates vehicle speed related.</td>
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<tr>
<td>5. Exhaust noise</td>
<td>3. Knowing the frequency and order is very helpful in diagnosing which component is generating the vibration.</td>
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<tr>
<td>6. Intake noise</td>
<td></td>
<td></td>
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<tr>
<td>7. Tire uniformity condition</td>
<td></td>
<td></td>
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<tr>
<td>Resonators</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Twisting of the driveline</td>
<td></td>
<td></td>
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<tr>
<td>2. Bending of the driveline</td>
<td></td>
<td></td>
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<tr>
<td>3. Exhaust pipe</td>
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<td></td>
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<tr>
<td>4. Rear suspension system</td>
<td></td>
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<tr>
<td>5. Outer body panels</td>
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<tr>
<td>1. Two vibrations are required and could be a combination of the following:</td>
<td>1. Torque converter imbalance will generate a beating with another vibration such as a propeller shaft vibration when the conditions are as described. Slippage of the torque converter can contribute to the difference in frequencies creating the beating.</td>
<td></td>
</tr>
<tr>
<td>Engine imbalance - 1st order</td>
<td>2. The vibrations are transmitted to the body through the engine mounts from the torque converter and the rear suspension from the propeller shaft.</td>
<td></td>
</tr>
<tr>
<td>Torque fluctuation - 2nd order 4cyl, 3rd order 6cyl</td>
<td>3. Correcting the propeller shaft may be the easiest repair.</td>
<td></td>
</tr>
<tr>
<td>Torque converter imbalance</td>
<td>4. Depending on the gear ratio of the transmission a beating can occur between an engine vibration and a driveline vibration if the frequencies of each are only slightly different.</td>
<td></td>
</tr>
<tr>
<td>Propeller shaft imbalance - 1st order driveline</td>
<td>5. Engine vibrations and accessory vibration can match to cause a beating noise. Removal of belts will help identify the accessory causing the vibration.</td>
<td></td>
</tr>
<tr>
<td>Flange runout - 2nd order driveline</td>
<td>6. Depending on differential gear ratio tire vibration and propeller shaft or engine vibrations can cause a beating noise.</td>
<td></td>
</tr>
<tr>
<td>Joint condition or angle - 2nd order driveline</td>
<td>7. Two imbalanced tires with a different radius can cause a beating noise.</td>
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<tr>
<td>Tire vibration</td>
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<tr>
<td>Cooling fan imbalance</td>
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<td>Alternator vibration</td>
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<tr>
<td>A/C compressor vibration</td>
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<tr>
<td>Power steering pump vibration</td>
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<tr>
<td>1. Engine noise can be improved by reducing the noise from the source or insulting against the noise.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. The following are examples:</td>
<td>1. Engine noise can be improved by reducing the noise from the source or insulting against the noise.</td>
<td></td>
</tr>
<tr>
<td>Holes plugged with grommets</td>
<td>2. The following are examples:</td>
<td></td>
</tr>
<tr>
<td>Asphalt sheets</td>
<td>Holes plugged with grommets</td>
<td></td>
</tr>
<tr>
<td>Sealer</td>
<td>Asphalt sheets</td>
<td></td>
</tr>
<tr>
<td>Sandwich steel sheets with insulators inside</td>
<td>Sealer</td>
<td></td>
</tr>
<tr>
<td>Pad for engine hood</td>
<td>Sandwich steel sheets with insulators inside</td>
<td></td>
</tr>
<tr>
<td>Specially designed engine mounts</td>
<td>Pad for engine hood</td>
<td></td>
</tr>
<tr>
<td>Vibrating force</td>
<td>Wind noise is generated when air hits or is swirled by an object. The sound enters through a door or window.</td>
<td>Wind noise is also caused by leakage through a gap. When the vehicle is moving, the pressure outside the vehicle is lower than inside and the noise is created when the air escapes.</td>
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<tr>
<td>-----------------------------------------------------</td>
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</tr>
<tr>
<td>1. Swirls of air generated by protrusions and steps in the body surface.</td>
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<tr>
<td>2. Leakage of air through gaps in the body.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SYMPTOM</td>
<td>SENSATION</td>
<td>CONDITIONS</td>
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</tbody>
</table>
| Transmission gear whine | 1. A high pitched clear sound that is noticed from the front seats.  
2. Frequency 400-3k Hz                                                                                                                                  | 1. It is specific to a particular gear position and is not heard when the gear is connected directly with the engine.                                                                                      |
| Differential gear whine  | 1. A high pitched, clear sound heard from the front of FF vehicles and the rear of FR vehicles.  
2. Frequency 400-1500 Hz                                                                                                                                 | 1. It occurs at medium speed 25-30 MPH regardless of gear position.  
2. When it occurs during acceleration, it will disappear when the pedal is released. When it occurs during deceleration, it will disappear when the pedal is engaged. |
| Clutch judder         | 1. The forward and backward shocks to the body when the clutch is engaged. It stops when the clutch is completely engaged.  
2. Frequency 10-20 Hz                                                                                                                                       | 1. It occurs when the clutch is partially engaged, starting from a stop, especially under a load such as an incline.  
2. It usually does not occur when the vehicle is in motion.                                                                                           |
| Take-off vibration    | 1. A slow and weak vibration of the body and steering wheel during initial acceleration.  
2. Frequency 15-30 Hz                                                                                                                                      | 1. It occurs when the clutch is slightly engaged with the engine at idle or when engaged abruptly at 800-900 RPM.  
2. A load such as an uphill grade can also contribute to the vibration.                                                                                       |
| Cranking vibration    | 1. A very slow vibration felt in the body and seat during cranking.  
2. Frequency 5-15 Hz                                                                                                                                     | 1. The vibration begins when the starter is activated and stops when the engine starts.                                                                                                                     |
| Idle vibration        | 1. A slow vibration of the body, steering wheel and seats.  
2. Frequency 10-50 Hz.                                                                                                                                     | 1. Engine idle, not moving, in gear or A/C on.                                                                                                                                                           |
| Brake vibration       | 1. A vibration of the dashboard, steering wheel and seats when the brakes are applied.  
2. It is felt at the pedal at the same frequency as the vibration.  
3. Frequency 10-30 Hz                                                                                                                                     | 1. Occurs when the brakes are applied at medium to high speeds.                                                                                                                                            |
| Brake squeak | 1. A very high pitched squeaking noise or low solid groan.  
|             | 2. More common from disc than drum brakes.  
<p>|             | 3. Frequency 5-20 Hz. | 1. Occurs when brake is applied lightly or heavily. |</p>
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<tr>
<th>CAUSES</th>
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<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibrating force</td>
<td>FR</td>
<td>1. Gear selection is the key to diagnosis between transmission and differential gear whine. 2. Familiarity with the transmission power flow will assist in determining which gear is 1:1 and the gears that could be in question. 3. Bearing noise is similar to gear whine and must be considered during disassembly.</td>
</tr>
<tr>
<td>1. Gear meshing error - nicked, worn or damaged tooth, incorrect teeth contact, gear runout and backlash, gear supporting rigidity</td>
<td>1. Inaccurate meshing of the transmission gears causes the gears to vibrate. 2. Gear vibration vibrates the transmission case, which vibrates the body panels via the rear engine support members. 3. Gear vibration is also amplified by the resonance of the propeller shaft and the rear suspension.</td>
<td></td>
</tr>
<tr>
<td>Resonators</td>
<td>1. Sound is transmitted from the transaxle case to the body via the engine mounting and shifter.</td>
<td></td>
</tr>
<tr>
<td>1. Gear vibration</td>
<td>FF</td>
<td>1. The noise is transmitted directly to the passenger compartment via the case, mounts, cables, and the air.</td>
</tr>
<tr>
<td>2. Transmission case</td>
<td></td>
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<tr>
<td>3. Engine supports and mounts</td>
<td></td>
<td></td>
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<tr>
<td>4. Propeller shaft</td>
<td></td>
<td></td>
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<tr>
<td>5. Rear suspension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Body panels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibrating force</td>
<td>FR</td>
<td>1. Intermittent slippage occurs when partially engaging the clutch, transmitting engine torque vibrations. 2. Induces a torsional vibration in the driveline. If resonance occurs, the vibration is amplified. 3. Amplified torque fluctuation is transmitted to the tires and rocks the vehicle back and forth.</td>
</tr>
<tr>
<td>1. Friction characteristics of the facing material and runout of the clutch disc</td>
<td>1. Foreign material such as oil or grease will contribute to the condition.</td>
<td></td>
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<tr>
<td>2. Unequal height of the diaphragm spring fingers</td>
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<td></td>
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<tr>
<td>3. Binding of the clutch cable or linkage</td>
<td></td>
<td></td>
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<tr>
<td>Resonators</td>
<td>1. Drive line</td>
<td></td>
</tr>
<tr>
<td>1. Drive line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibrating force</td>
<td>FF</td>
<td>1. Take-off vibration is also caused by coupling created by a joint angle of the three joint propeller shaft on FR vehicles. In this case, the vibration is transmitted to the floor by the center carrier, causing the shifter and floor to vibrate. 2. It is also caused by a wind-up on vehicles with rear leaf springs.</td>
</tr>
<tr>
<td>1. Torque fluctuation of the engine</td>
<td>1. When the clutch is partially engaged during initial vehicle movement, the engine RPM drops momentarily and results in a major torque fluctuation. This causes a rolling vibration of the engine. 2. The vibration is transmitted via the engine mounts to the body. The engine sometimes hits the mounting stops. The instrument panel and steering wheel shake as a result.</td>
<td></td>
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<tr>
<td>Resonators</td>
<td>1. Engine mounts</td>
<td></td>
</tr>
<tr>
<td>1. Engine mounts</td>
<td></td>
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<tr>
<td>2. Body</td>
<td></td>
<td></td>
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<tr>
<td>3. Steering wheel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibrating force</td>
<td></td>
<td>1. A heavy hitting noise could be associated with this condition if components such as the exhaust contact the body.</td>
</tr>
<tr>
<td>1. Torque fluctuation during starting of the engine</td>
<td>1. Engine rolls due to the fluctuation in compression. 2. This movement acts on the mounts causing the body to shake.</td>
<td></td>
</tr>
<tr>
<td>Resonators</td>
<td>1. Engine mounts</td>
<td></td>
</tr>
<tr>
<td>1. Engine mounts</td>
<td></td>
<td></td>
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<tr>
<td>2. Body</td>
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</tr>
<tr>
<td>Vibrating force</td>
<td></td>
<td>1. Transverse mounted engines are more prone to this type of vibration and have specially designed mounts and exhaust systems.</td>
</tr>
<tr>
<td>1. Torque fluctuation of the engine</td>
<td>1. Torque fluctuation causes a rolling vibration which is worse if under a load or in poor operating condition. 2. The engine vibration is transmitted to the body through the mounts. 3. The exhaust system will also vibrate and will be transmitted to the body by the O-rings. 4. The body vibration will cause the steering wheel and seat to vibrate.</td>
<td></td>
</tr>
<tr>
<td>Resonators</td>
<td>1. Engine mount</td>
<td></td>
</tr>
<tr>
<td>1. Engine mount</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Exhaust pipe and supports</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Body</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibrating force</td>
<td></td>
<td>1. Lug nut torque is important to minimize the chance of the unequal strain contributing to the condition. 2. If it occurs at high speed the tires should also be checked for runout which could contribute to a brake vibration.</td>
</tr>
<tr>
<td>1. Rust or runout, in the rotor or drum</td>
<td>1. Runout of the rotor causes the pad to vibrate during braking. 2. The pad vibration is transmitted along the brake hydraulic circuit and causes the pad to vibrate. 3. It is also transmitted to the rotor, steering knuckle, axle shaft or hub, causing an up and down or front to back vibration. 4. The vibrations are transmitted to the body via the suspension system causing a shake.</td>
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<tr>
<td>2. Runout of the rear axle flange</td>
<td></td>
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<tr>
<td>3. Runout of the rotor and rim mating surface</td>
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<tr>
<td>Resonators</td>
<td>1. Pad</td>
<td></td>
</tr>
<tr>
<td>1. Pad</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Brake pedal</td>
<td></td>
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<tr>
<td>3. Steering knuckle, axle hub or shaft</td>
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<td></td>
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<tr>
<td>4. Suspension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Body</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibrating force</td>
<td>1. The friction surface between the brake components causes a vibration which resonates with the rotor, drum or backing plate.</td>
<td>1. It is important that the anti-squeal components are in place during installation.</td>
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</tr>
<tr>
<td>1. Fluctuation and friction of the pads Resonators</td>
<td></td>
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</tr>
<tr>
<td>1. Pads or shoes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Rotor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Drum and backing plate</td>
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</tbody>
</table>
**Introduction**

An organized, systematic procedure is important in any type of diagnosis. It is the most efficient/cost effective way to resolve complaints the first time. NVH complaints are sensed by feeling or hearing and are therefore, very subjective in nature.

A good **systematic diagnostic procedure** is critical to deal with these types of complaints because the symptoms may not clearly point to the condition. Systematic diagnostic procedures will help you successfully resolve NVH conditions as they do with difficult computer and electrical problems.

Elements incorporated in a systematic diagnostic procedure are:

- An organized **process of elimination** which prioritizes activities to quickly isolate the condition
- A thorough **visual inspection** for obvious conditions or clues to help diagnose the condition

**NOTE**

In order to apply these elements to NVH troubleshooting, a solid understanding of the NVH theory in Section 1 is important. Diagnosis applies the theory to isolate the condition. An incorrect diagnosis usually results from a poor diagnostic procedure, a lack of understanding on how the system works or both.

This section of the course will address in detail the first three items of the NVH diagnostic procedure:

- Verify the complaint
- Classify the complaint
- Road test with NVH analyzer

Practice implementing the NVH diagnostic procedure will be accomplished by following **two customer complaint scenarios or case studies**.

- The first scenario is incorporated in this section of the technician handbook.
- The second is part of the worksheet activities.
Lesson Objectives

1. Develop skills in the use of NVH Diagnostic Procedures.
2. Demonstrate the ability to verify the customer complaint.
3. After verifying the complaint select the appropriate course of action:
   • Customer consultation
   • Technician diagnosis and repair
   • Technical assistance
4. Demonstrate the ability to classify the customer complaint using the:
   • Customer Interview Sheet
   • Classification Flow Chart
5. Differentiate between the purpose of a test drive with the customer to verify the complaint, and the road test for diagnosis.
6. Given a list of road test procedures, select a road test appropriate for the symptoms.
7. Develop skills using the NVH Analyzer.
   • Set-up
   • Data Displays
   • Data Analysis
8. Determine the source and order of the vibration or noise using the NVH Analyzer.
9. Differentiate between conditions that are serviceable versus non-serviceable.
10. Determine the appropriate use of a lift or safety stands for diagnosis.
11. From the use of the NVH diagnostic procedures, demonstrate the ability to draw conclusions that will allow you to develop a pinpoint diagnostic plan.
1. Verify the Customer Complaint
2. Classify the Complaint
3. Road Test
4. Pinpoint Diagnosis
5. Perform the Repair
6. Verify the Complaint has been Resolved

Fig. 2-1
Case Study: Background

In order to help illustrate the concept of NVH diagnosis we will apply the principles outlined above to a customer complaint involving a 4Runner. Each topic in this section will be applied to the scenario and at the end of the section the condition will be resolved.

The details of the diagnostic scenario are contained in the following repair order. They are also included in each procedure and illustration as it applies.
Each area of this section includes a worksheet which is based on a customer complaint scenario. Your instructor has created a similar problem in a shop vehicle for you to troubleshoot.

Detailed information and instructions for the worksheets will be provided by your instructor. Upon completion of each worksheet, the complaint should be resolved on the shop vehicles.

Verification of the customer complaint is a key starting point in an NVH diagnostic procedure for two reasons:

- If the complaint can’t be verified, a plan can be implemented that involves satisfying the customer through education or returning the vehicle for service when the complaint can be duplicated.
- It is important that the technician experiences exactly what the customer is complaining about and knows what is involved to satisfy the customer.

There are three courses of action to successfully resolve an NVH complaint:

1. Customer consultation
2. Technician diagnosis and repair
3. Technical assistance for non-serviceable conditions

Starting a diagnostic procedure implies that there is a problem with the vehicle. The service department is then committed to the second or third course of action. If it is discovered after the diagnosis begins that the complaint was not verified, then it is difficult to step back to the first course of action and customer satisfaction is very difficult.

The earlier the appropriate course of action is chosen the more likely a positive service experience will occur.
The Interview sheet is a tool designed to solve one of the largest problems identified in NVH service, poor communication. Proper communication helps you educate the customer and ensures an appropriate course of action can be taken.

Research involving unresolved NVH complaints indicates that technicians often start a diagnosis without knowing the exact details of the complaint. This results from a lack of communication with the customer which wastes time or causes a missed diagnosis.

Good communication skills include:

- **Description or terminology** that mean the same thing to all parties involved.
- **Time** to help the customer clarify the complaint. (The customer is not expected to know the technical terms of the automotive industry).
- **Information** collected in an organized manner.

A customer, when properly interviewed, can provide a wealth of information to start the diagnosis and process of elimination.

It is important to determine if the person bringing the vehicle in for service is the primary operator of the vehicle. Often, vehicles are brought in for service by someone who has no knowledge of the complaint.

The interview process is designed to help the customer focus on details of the NVH complaint and vehicle conditions when the complaint occurs.

The interview sheet provides a format to communicate these conditions using standard NVH terminology.

Verification of the complaint is also a critical area of diagnosis, when the condition is intermittent or only occurs under specific conditions.

For example:

Noises from suspension components may be much more pronounced at ambient temperatures below 40°F. If these temperature conditions are not present at the time of diagnosis, the technician may not experience the complaint to the same degree as the customer.

The technician needs to experience the condition and be able to duplicate it in order to accurately diagnose it. The more details that are available, the more likely the condition can be found quickly.

An additional benefit of the interview sheet is the documentation of the communication with the customer. It provides a history of the service experience. In the event the complaint can’t be verified, this documentation will provide valuable information in the event of subsequent service visit.
Customer Interview Sheet

Continued

The customer interview sheet is designed to be as short and concise as possible. The information collected is divided into the following areas:

- Customer data
- Vehicle data
- NVH data

---

**Interview Sheet for 4Runner**

Fig. 2-3

---

**CUSTOMER INTERVIEW SHEET**

**INSTRUCTIONS**

This sheet should be completed and the interview filled out by personnel trained in NVH (Noise, Vibration, Harshness) techniques. Please fill it out as completely as possible, even if some items do not apply.

**CUSTOMER DATA**

Name ____________________________ Date ____________________________
Email ____________________________ Phone ____________________________

**VEHICLE DATA**

Model Year ____________________________ Make ____________________________
Model ____________________________ Mileage ____________________________

**I. Customer interview the primary operator of the vehicle?** Yes No

**II. NVH DATA**

- Which area of the vehicle is experiencing NVH issues? Noise, Vibration, Harshness
- Condition: Occasional, Intermittent, Gradually, Sudden
- Noise: Describe the noise: Engine, Exhaust, Wind, Interior

**III. Vibration**

- Vibration source: Brake Pedal, Steering Wheel, Instrument Panel, Floor, Seat, Door
- Describe the vibration: Vertical, Horizontal, Imperceptible

**IV. Harshness (Ride Quality)**

- Where do you experience it? "I do not feel it"
- Where do you experience it? "I do feel it"
- Do you feel any other NVH issue? Yes No

---

**LOCATION INDICATOR**

---

**OPERATING CONDITION**

- When was the condition observed? Daytime Nighttime
- Vehicle speed (mph): _______________

---

**WEATHER CONDITIONS**

- Temperature: _______________
- Rain: _______________
- Snow: _______________
- Wind: _______________

---

**ADDITIONAL INFORMATION**

__________________________________________________________

---
Customer Interview Sheet

Continued

Customer and vehicle data are for obvious logistical and administrative purposes. The value of this data becomes clear if future tracking of the customer, the vehicle or an NVH condition is required.

---

**CUSTOMER INTERVIEW SHEET**

**INSTRUCTIONS**

The interview should be conducted and the sheet filled out by personnel trained in NVH diagnosis. Please fill in or check all areas with the appropriate response, enter N/A if it does not apply. The details collected during the interview are critical in successfully resolving the concern.

**CUSTOMER DATA**

Name: Anybody, John
Telephone #: (310) 555-1001
Date: 7/26/94

**VEHICLE DATA**

Model/Year: 19400
VIN #: JTBUI1EOP014931
Mileage: 25318

Is the customer the primary operator of the vehicle? ☑ Yes ☐ No

---

The NVH data is organized to provide the details of the complaint and data on conditions present when the complaint occurs.

**Communication** is the key objective of the interview sheet and should be done by trained service personnel to provide assistance and clarification. Technician involvement in the interview may be required to allow direct communication and minimize problems created by passing information through a third person.

Begin the interview by asking the customer to classify the concern by selecting one or more of the following:

- Noise
- Vibration
- Harshness

The next question determines whether the condition is constant or intermittent.

The customer should also be asked if the complaint has developed while operating the vehicle or whether it has been present since the vehicle was new. This information will be useful to the technician in determining which course of action to select, either technician diagnosis or technical assistance.
The customer is provided with a list of possible locations with a few details specific to each location.

For example:

If the steering wheel is the location then there are three possible types of steering wheel vibrations:

- Vertical
- Horizontal
- Rotational

Using this information, in conjunction with the classification flow chart (discussed later), will considerably reduce the large list of possible causes of the condition.

**NVH Data**

**NVH Data**

- **What type of condition is the customer experiencing?** Noise, Vibration, Harshness (ride quality)
- **Is the condition constant?** Constant, Intermittent, Other
- **When did it start?** Always in Service, Since New, Gradually, Suddenly, Other

**NOISE**

- **Describe the noise:** Squeak, Rattle, Wind Noise, Other
- **At Highway Speed**

  - **Note here and mark the location of the noise on the illustration (reverse side of this form).**
  - **From the rear**

**VIBRATION**

- **Where is it felt?** Steering Wheel, Floor, Seat, Instrument Panel, Shifter, Body, Mirrors, Clutch Pedal
- **Describe the vibration:** Vertical, Horizontal, Rotational, Other

**HARSHNESS (Ride Quality)**

- **Where do you experience it?** N/A
- **When do you experience it?** N/A
- **Has the vehicle ever been damaged?** Yes, No
- **Is there any relevant service history?** Yes, No
- **Has there been any accessory installation?** Yes, No
- **Is the vehicle used for towing or to carry any cargo or equipment?** Yes, No

**LOCATION INDICATOR**

- Noise is coming from the rear of the vehicle.
Customer Interview Sheet

The **conditions section** of the interview sheet is designed to collect data for the following subjects:

- Operating conditions
- Vehicle conditions
- Road conditions
- Weather conditions

Each of these areas have specific conditions to select, which will provide the technician with the details necessary to **duplicate the complaint**.

Each area has space provided to record information on unique complaints or conditions that fall outside the parameters outlined in the interview sheet.

The interviewer should cover **all areas** that apply to the complaint. **N/A** should be entered in areas that do **not** apply, indicating to the technician that the customer considered the subject and did not overlook it.

The customers should be aware of the **key role they play in resolving the complaint**.

### Operating Condition

<table>
<thead>
<tr>
<th>When does the condition occur?</th>
<th>Starting</th>
<th>Idling</th>
<th>Cruise</th>
<th>Coast</th>
<th>Other</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Vehicle Speed (MPH)</th>
<th>40-60</th>
<th>Engine Speed (RPM)</th>
<th>N/A</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Cornering</th>
<th>Cornering</th>
<th>Acceleration</th>
<th>Deceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>Right</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Braking</th>
<th>Clutch Engagement</th>
<th>Other</th>
<th>N/A</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Accessories</th>
<th>HVAC</th>
<th>4WD</th>
<th>Audio</th>
<th>Other</th>
<th>N/A</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Engine Temperature</th>
<th>Cold</th>
<th>Normal</th>
<th>Hot</th>
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<tbody>
<tr>
<td>Highway</td>
<td>Suburb</td>
<td>City</td>
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</table>

<table>
<thead>
<tr>
<th>Road Conditions</th>
<th>Asphalt</th>
<th>Dirt/Off Road</th>
<th>Concrete with Expansion Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undulating</td>
<td>Other Irregularities</td>
<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Explain</th>
<th>N/A</th>
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</table>

### Weather Conditions

<table>
<thead>
<tr>
<th>Temperature</th>
<th>N/A</th>
<th>°F</th>
<th>Clear</th>
<th>Rain</th>
<th>Ice/Snow</th>
<th>Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<table>
<thead>
<tr>
<th>Other</th>
</tr>
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</table>

### Additional Information

<p>| |</p>
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</tbody>
</table>
Summary  At this point in the diagnosis the technician has:

• A completed repair order
• A completed interview sheet
• Verified the complaint
• Chosen one of three course of actions

The technician can now proceed with a plan for customer consultation or NVH diagnosis equipped with a strong background of the complaint.

Case study: Part I  In the 4Runner scenario the customer has filled in the customer and vehicle data sections. This has to be reviewed to make sure that it is completely filled out.

The customer has indicated to the interviewer that he is the primary driver and has experienced the complaint.

The NVH data indicates the following areas have been selected during the interview:

Classify

• Noise other than squeak, rattle or wind noise
• Vibration

They are both constant and started gradually. The vibration is felt in the steering wheel and is rotational. The sound is heard in the rear of the vehicle.

Operating conditions

• 40 - 60 MPH
• Cruise
• Coasting

It is also important to note that the following data has not been selected:

• Since new
• Engine RPM
• Vehicle condition section
• Weather condition section
• Road condition section

The fact that these areas were marked N/A indicates that the condition has developed while in service, engine speed does not effect it and that it is always there once the vehicle speed range is reached.

For the purposes of this scenario the technician has gone for a short ride with the customer and has verified that the complaint does exist as described.

The technician has also chosen the second option, technician diagnosis and repair, based on the information and verification available. The technician agrees that an unacceptable condition does
exist. The customer has indicated that the vehicle has recently developed the condition.
WORKSHEET #1
Verification of the Customer complaint

Diagnostic Description: **Verify the Complaint**

It is critical for the technician to **experience** the complaint for it to be successfully resolved. The Customer Interview Sheet is a **tool**, used by trained NVH service personnel, to collect the details associated with the customer complaint. With the information from the interview the technician can easily **duplicate** the symptom and gain valuable insight for diagnosis.

Your instructor has created **typical NVH conditions** in the shop vehicles. The completion of worksheets 1, 2, 4A and 4B will provide **practice** using the NVH diagnostic procedures and **resolve** the conditions on these vehicles. Worksheets 3A, 3B and 3C will provide **experience** using the NVH Analyzer.

**NOTE**
Your instructor will also act as the customer providing the information necessary to complete the first step, the customer interview (Copy Attached).
Instructions

1. **Conduct** the customer interview with the customer/instructor by asking all the questions on the attached sheet.

2. Your instructor will act like a customer and may not understand the question or the terminology used. Be sure to provide **clarification and explanations** as necessary.

   You may need to ask probing questions to determine if the customer understands the questions. They may not easily indicate that they don’t understand.

   The questions asked during this process may prompt the customer to provide additional, valuable information that they may not normally think of as important. You are the NVH expert, not the customer.

   It is important that the interview be conducted and the sheet filled out by personnel trained in NVH service. The customers should **not** be left to fill out the sheet on their own. Trained personnel can provide assistance, as necessary, to ensure high quality information about the complaint.

3. When the interview is complete, **review** all the data collected and **answer** the following questions. If the review or the following questions identify a lack of information, conduct that portion of the interview again.

4. Take a quick **test drive** with the customer to experience the complaint and determine what needs to be done to satisfy the customer.

5. Refer to the **Technician Handbook** for additional information to answer the following questions.

Questions

1. What is the difference between a **test drive** with the customer and a **road test** performed during diagnosis?

2. What is the reason for knowing who is the **primary operator** of the vehicle?
Questions (continued)

3. If the person who brings the vehicle in for service is **not** the primary operator, what is your **plan of action**?

4. What value is it to have **precise vehicle data** when conducting a **road test**? (i.e. year, trans, axle, tire size)

5. What is the **value** of knowing:
   - Service History
   - Damage History
   - Accessory installation

6. If the customer indicates that there **has** been one of the above situations with the vehicle (question #5), what would your **next questions include**? Please list and explain.
   
   **Where** would you **record** this information?
Questions (continued)

7. What is the pitfall associated with assuming the customer understands the meaning of NVH terms, such as “harshness”.

8. When should the operating conditions be determined to maximize a positive service experience and why?

9. What information is provided when the interviewer enters N/A as an answer?

10. What is the advantage to filling in the final details the customer could not answer, during the test drive?

11. What is the value of having the interviewer and customer review and sign the interview sheet?
Conclusions

1. **List** the information from the interview sheet that is relevant to **resolving** the complaint. Briefly explain each.

   ______________________________________________________
   ______________________________________________________
   ______________________________________________________
   ______________________________________________________
   ______________________________________________________
   ______________________________________________________

2. From the information gathered at this point, what **test drive techniques** are necessary to **duplicate** the symptoms? Explain.

   ______________________________________________________
   ______________________________________________________
   ______________________________________________________
   ______________________________________________________

3. Based on the information collected from the interview sheet and the test drive, which of the following **course of actions** would you choose and why?

   - Customer Consultation
   - Technician Diagnosis and Repair
   - Technical Assistance for non-serviceable conditions

   ______________________________________________________
   ______________________________________________________
   ______________________________________________________

4. If **customer consultation** is chosen, what is your **plan of action**? Explain.

   ______________________________________________________
   ______________________________________________________
   ______________________________________________________
   ______________________________________________________
5. What is the **pitfall** associated with **starting** a diagnosis **before** the verification process is complete?
**CUSTOMER INTERVIEW SHEET**

**INSTRUCTIONS**
The interview should be conducted and the sheet filled out by personnel trained in NVH diagnosis. Please fill in or check all areas with the appropriate response, enter N/A if it does not apply. The details collected during the interview are critical in successfully resolving the complaint.

**CUSTOMER DATA**
Name: ___________________________ Date: ___________________________
Telephone #: ___________________________ RO #: ___________________________

**VEHICLE DATA**
Model/Year: ___________________________ Mileage: ___________________________
VIN #: ___________________________
Is the customer the primary operator of the vehicle?  ○ Yes  ○ No

**NVH DATA**
What type of condition is the customer experiencing?  ○ Noise  ○ Vibration  ○ Harshness (ride quality)
Is the condition constant?  ○ Constant  ○ Intermittent
When did it start?  ○ While in Service  ○ Since New  ○ Gradually  ○ Suddenly
○ Other ___________________________

**NOISE**
Describe the Noise:  ○ Squeak  ○ Rattle  ○ Wind Noise  ○ Other ___________________________
When does the noise seem to be the loudest or most frequent?
____________________________________________________________
Note here and mark the location of the noise on the illustration (reverse side of this form).
____________________________________________________________

**VIBRATION**
Where is it felt:
- ○ Steering Wheel  ○ Floor  ○ Seat  ○ Instrument Panel
- ○ Brake Pedal  ○ Console  ○ Accelerator Pedal
- ○ Shifter  ○ Body  ○ Mirrors  ○ Clutch Pedal

Describe the vibration:
- ○ Vertical  ○ Horizontal  ○ Rotational
- ○ Other: ___________________________

**HARSHNESS (Ride Quality)**
Where do you experience it? ___________________________
When do you experience it? ___________________________

Has the vehicle ever been damaged?  ○ Yes  ○ No  If so, please indicate where on the illustration.
Is there any relevant service history?  ○ Yes  ○ No  If so, please describe: ___________________________
Has there been any accessory installation?  ○ Yes  ○ No ___________________________
Is the vehicle used for towing or to carry any cargo or equipment?  ○ Yes  ○ No ___________________________
LOCATION INDICATOR

OPERATING CONDITION

When does the condition occur?  ○ Starting  ○ Idling  ○ Cruise  ○ Coasting  ○ Other ___________

Vehicle Speed (MPH): _______________  Engine Speed (RPM): _______________

○ Cornering Left  ○ Cornering Right  ○ Acceleration  ○ Deceleration

○ Braking  ○ Clutch Engagement  ○ Other _______________

Accessories:  ○ HVAC  ○ 4WD  ○ Audio  ○ Other _______________

Engine Temperature:  ○ Cold  ○ Normal  ○ Hot

Road Conditions:  ○ Highway  ○ Suburb  ○ City

Road Surface:  ○ Asphalt  ○ Dirt/Off Road  ○ Concrete with Expansion Joints

○ Undulating  ○ Other Irregularities

Explain: ________________________________________________

WEATHER CONDITIONS

Temperature: _____ °F  ○ Clear  ○ Rain  ○ Ice/Snow  ○ Wind

○ Other ________________________________________________

ADDITIONAL INFORMATION

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Classify the Complaint

During diagnosis a technician has to take a **large list** of possible NVH conditions and, through a **process of elimination**, find the one that applies to the situation.

**Symptoms Classification Flow Chart**

![Symptoms Classification Flow Chart](image-url)

---

**CLASSIFICATION FLOW CHART**

- **Driving at high speed**
  - Seat, steering wheel and floor vibrate vertically and horizontally
  - Steering wheel vibrates in direction of rotation

- **Driving at low or medium speed**
  - Accelerator pedal vibration
  - Shift lever vibration
  - Ride discomfort

- **Driving at all speeds**
  - Single and vibrations at bumps and joints in road
  - Harshness
  - Flood noise

- **Constant sound regardless of vehicle speed**
  - Pitch of noise becomes higher as speed increases

- **Take off noise**
  - Body booming noise
  - Body booming noise

- **Low, heavy sound**
  - Occurs at certain engine or vehicle speeds only
  - Proportional to vehicle speed and wind direction
  - Related to shift lever position
  - Unrelated to shift lever position

- **High, deep sound**
  - Engine noise
  - Wind noise
  - Transmission gear whine
  - Differential gear whine

- **Shaking**
  - Clutch chatter
  - Take-off vibration
  - (Acceleration vibration)
  - Cranking vibration
  - Vibration at idle

- **Idling**
  - Vibration during braking
  - Brake squeak

---
Once the complaint has been classified, a specific diagnostic approach can be applied which will identify the source. This eliminates random diagnosis resulting in wasted time, confusion and frustration.

A further advantage of this organized style of diagnosis is that it allows the technician to trace the steps. The point where a decision was made, which led to a wrong, diagnosis can be identified. Only the necessary procedures need to be repeated to successfully find the condition.

Classification is done by collecting information about the complaint that is unique to the condition. Each step in the process eliminates possibilities until there is only one left.

Efficient diagnosis prioritizes the procedures that eliminates the largest number of possibilities first. This process will minimize the number of tests required and will be less likely to send the technician looking in the wrong direction.

The four tools available in the classification process are:

- Customer interview sheet
- Flow chart for classification
- Road test
- NVH Analyzer

With the data collected from the complaint verification and interview sheet, the technician can follow a path through the flow chart by making yes or no decisions at each level of the chart.

If a decision can’t be clearly made at a specific point in the chart, then a point has been identified where more information is needed, and exactly what that information has to include.

Successful completion of the flow chart will provide the technician with a classification for the symptoms which can be associated with specific characteristics. These specific characteristics can only be caused by one area on a vehicle and pinpoint diagnosis can be focused on that area for the cause and repair (See Section 1 for the specific characteristics).
The recent emphasis placed on NVH in automobiles has brought with it a **new vocabulary**. In addition, **quality communication** from the customer to the technician, has been identified as one of the major areas of concern for successful NVH service.

**Standardized** NVH terminology is very important to ensure that everyone understands the conditions in the same way. The flow chart is a **tool** used by the technician to identify the symptom from the data collected during the interview and the test drive.

When the proper symptom is selected from the list, there are **specific characteristics** associated with the term which are helpful in diagnosis. For example, the **frequency** of the symptom.

---

**Classification Flow Chart**

![Classification Flow Chart](image)
Section 2

Instructions
As indicated in worksheet #1, this worksheet is the second worksheet designed to:

• provide an opportunity to practice the NVH diagnostic procedure
• resolve the condition placed in the shop vehicles.

1. Use the information collected on the customer interview sheet and the test drive (worksheet #1) to answer the questions at each branch of the flow chart. (attached)

2. If you cannot clearly answer the questions on the sheet then you have identified an area that requires more information. Determine if it has to be collected from the customer/instructor or another test drive.

3. Review the characteristics of each symptom on the symptom chart (Section 1 of the student handbook) and answer the following questions.

Questions
1. How many symptoms were identified?

2. List the symptom/s below.

3. Is the symptom/s noise, vibration, harshness or a combination?

4. What are the frequencies associated with the symptom/s?

5. Why will knowing the frequency be helpful during diagnosis?

6. What other things are you familiar with in your daily life which operate at the same frequency? Why is this helpful in diagnosis?

7. Are the symptoms engine speed related, vehicle speed related or both?
Questions (continued)

8. What **conditions**, listed on the symptom chart (Section 1) are the **same** as gathered during the interview sheet and the test drive?

   What **conditions** are **different**?

9. **List** the possible **causes** from the symptom chart (Section 1) that are most likely in this case. **Explain**.

10. What is the **vibrating system** related to the symptom?
   - Vibrating force: ____________________________
   - Resonance system: ____________________________
   - Transmission system: ____________________________
   - Vibrating body: ____________________________

11. Does the vibrating system from the symptoms chart (Section 1) and the one associated with this case **match**?

12. Remember, not all cases follow a text book situation exactly, the chart serves as a **guide** for most cases.

   What is your **plan of action** in the event that the case being diagnosed is **not** exactly the same as the symptoms outlined in the chart?

Conclusions

The information generated with this flow chart will be used with the customer interview sheet, the NVH analyzer, and the road test to classify the complaint and identify the possible source of the vibration or sound. (engine, driveline or wheels)

A successful pinpoint diagnosis can be done with solid background information on the complaint.
Case study: Part II  After the technician has verified the complaint, the classification flow chart is used to establish that there are two areas or classifications, for the symptoms.

- Steering shimmy
- Body booming

In the first level of the flow chart there are four choices:

- Driving (coasting)
- Take-off
- Standing
- Braking

**Driving** was selected because the symptoms occur between 40 - 60 MPH.

The second level asks if the symptoms are related to vibration or noise. In this case both areas need to be considered because there is a vibration in the steering wheel and a noise from the rear of the 4Runner.

The next level under vibration asks for the speed. The vibration is noticed first at about 40 MPH which is considered to be medium speed.

The chart next asks if the steering wheel vibrates in the direction of rotation. The term to describe this symptom is steering shimmy.

The next level after noise asks for speed. In this case the noise is most noticeable at speeds above 50 MPH. Driving at medium or high speed is the choice that best fits the noise symptom.

Next, you are asked if the noise varies or is unrelated to road condition. Unrelated best fits in this case. The customer noted, and the verification indicated, that the noise is always there once the proper speed is reached.

The sound is best described as a low and heavy sound as opposed to high clear sound and is related to vehicle speed.

The final question relating to noise asks if it is continuous or cyclic. The noise in the 4Runner scenario is described as being continuous which points to a body booming classification for the noise.

This may seem to be a complex way to arrive at a description of a symptom. But using this process and the flow chart insures that the proper terms are being used and mean the same thing to everyone involved.

In addition, there are very specific causes associated with each of these classifications which help the technician narrow down the list of possibilities. If the wrong term is used it could lead to a pinpoint diagnosis in the wrong area, wasting time.
Road Test  Diagnostic road testing is done after the complaint has been verified. Customers are helpful in verifying the complaint but do not need to be part of the complete diagnostic process. Unfortunately, some diagnostic procedures do not separate the verification of the complaint from the road test. The road test is designed to help isolate the condition after it has been verified. Data collected from a customer and data collected from a road test are different and serve two different functions.

During the road test, the technician duplicates the complaint under several specific operating conditions. This is done to identify unique characteristics which will help classify the complaint. In addition to duplicating the complaint, the technician should try to change or eliminate the symptom using techniques such as different speeds, RPM, load or other operating conditions.
The road test is designed to get the most information in the shortest amount of time. It is also part of a process of elimination reducing a large list of possibilities to the one causing the complaint.

The **condition of the vehicle must not be modified** prior to the road test. A thorough visual inspection may find conditions such as low tire inflation. Properly inflating the tires prior to the road test may modify the vehicle to the point that the symptoms may be effected.

Once the complaint has been verified the road test can be **modified specifically to the complaint**. Only conditions that apply to the complaint need to be duplicated.

For example:

If the condition occurs at a specific speed then road test parameters that do not apply to that condition do not need to be performed, like engine idle in Neutral or Park.
Collecting, Reading and Analyzing NVH Data

During the road test, the ability to **quantify the frequency and the level** of the vibration or sound is very useful for diagnosis. It also provides an **objective basis for comparison**.

Knowing the **frequency** of the condition will help classify the symptom. The large list of possibilities can be reduced considerably due to the fact that only specific components operate at specific frequencies.

A vibration analyzer, such as the **Toyota NVH Analyzer**, can measure the level of a specific frequency vibration or sound. This level can be recorded and compared to known good vehicles as well as the complaint vehicle, after the repair has been performed.

If a frequency analyzer is not available, experience with **known vibrations** is helpful in diagnosis. This approach, however, is very subjective when comparing levels of noise or vibration (See Section 1 for details).
The Diagnostic tool set includes an extensive **Operator’s Manual** with **operating instructions** for each program card. These references provide an excellent resource for the following information:

- Hardware
- Features
- Operating precautions
- Getting started
- Using the RS232 and instrumentation ports

The appendices provide valuable additional information to help the operator get the most out of the Diagnostic Tool Set (See operator’s manual table of contents).

The operating instructions provide details on the NVH Analyzer functionality. When one of the program cards is selected, the instructions will walk the operator through the menu selections and key strokes until the appropriate data is displayed. It will also explain how to move through the different displays, modify the displays and how to pause or snapshot the data. **Interpreting the data is left to the technician.**
Description: The NVH Analyzer Set-up

The NVH Analyzer is designed to be very **user friendly**, with the **minimal** menu selections required to select the vehicle and access the data displays.

This worksheet is designed to orient you to the **NVH menus** and the **active keys** on the analyzer.

**Toyota Diagnostic Tester**

Fig. 2-12

1. Display
2. and arrows move the cursor on the menu screens or changes amplitude on the display screens
3. and arrow move the cursor on all screens and displays
4. key changes the company on the program ID screen
5. displays a summary of active keys
6. with will print the screen
7. moves forward through the menu
8. key changes NVH displays
9. key changes the source indicators
10. key changes frequency band width
11. key saves a paused screen
12. key pauses the display
Instructions

1. **Install** the NVH Training Software card.

2. Refer to the NVH section of the Diagnostic Tool Set **Operator’s Manual** (Sections 1.0 - 3.0) and follow the procedures outlined to familiarize yourself with the operators manual, menu structure, active keys, and functions.
   - 1.0 Getting Ready
   - 2.0 Vehicle and System Selection
   - 3.0 NVH Main Menu

3. Press the **HELP** key frequently to familiarize yourself with the **help information** available in the software. Use the **EXIT** key to return to the menu or data displays.

4. Perform the **selection procedures** on the following vehicles and note the different selections required to access the NVH data displays.
   - 93 4Runner, 3VZ-E-4WD, AXLE G254, MT 10.5R15
   - 93 Supra
   - 93 Tercel, 4speed MT and AT

5. **Repeat** a vehicle selection from above using the “LAST VEHICLE” selection. **Note** the menus eliminated using this selection compared to the “NEW VEHICLE” selection.

   **NOTE** An auxiliary power source is recommended during this worksheet to avoid interruptions from a dead battery. (Refer to the operators manual section, “Powering the Diagnostic Tester”)

Questions

1. Which key moves **forward** through the menu structure?

2. Which key moves **back** through the menu structure?

3. What are the **two ways** to select “NVH” on the Function Select Menu?

4. What is the **purpose** of selecting the vehicle **specific** year, engine, transmission, etc.?

5. What effect will the **wrong** vehicle or vehicle parameters selection have on **diagnosis**? How will you know?

6. What is the **advantage** to using the “LAST VEHICLE” selection when possible?
Questions (continued)

7. List the resources available to verify the vehicle axle ratio.

8. Under what conditions would the axle ratio need to be changed? Be specific.


10. Does the tool tell you where to connect the data link cable on the vehicle selected?
    If so, which screen?

11. What is your plan of action if you get the “NVH Signal Conditioner Failure” screen? Explain.

12. What is the printer “Baud Rate” default value? Where did you find the answer?

13. How many unit conversions can be modified?
    List the ones applicable to NVH.

14. What type of information is available through “help”?
Description:  The NVH Analyzer Data Displays

The NVH software provides three data displays for NVH diagnosis.

- 2d (2 dimensional)
- Barchart
- 3d (3 dimensional)

These displays are available to analyze the vibrations and noise in a vehicle. They are accessed after the vehicle and function selections are made. (worksheet #3A) In addition to the vehicle vibrations, each display provides information including:

- Vibration indicator arrows
- MPH & RPM
- Time
- Frequency and amplitude

This worksheet is designed to review each of the displays in detail for the information available and the key strokes necessary to manipulate the information.

2d Display

Fig. 2-13
Section 2

Instructions

1. Install the NVH training software card.

2. Perform the **set-up procedures** outlined in the NVH section of the operator’s manual (Sections 1.0 - 3.0).
   - 93 Previa, 4wd AT
   - 93 Celica, 5S-FE, convertible
   - 93 Corolla, 4A-FE, DLX

3. Refer to **Sections 4.0 - 6.0** for details relating to each of the displays and functions.
   - 4.0 NVH Displays
   - 5.0 Pause Mode
   - 6.0 Data Record

4. **Practice manipulating** the displays with the active keys to learn the range and function of the data available for diagnosis.

Questions

1. What do the two axises represent on the 2d display?
   - Vertical
   - Horizontal

2. What are the **active keys** on the 2d display that change the:
   - amplitude
   - frequency (for each direction)
   - source indicator (engine, driveline and wheel)
   - cursor

3. **How many** ranges or bands are available for:
   - Amplitude
   - Frequency

4. If the time is **not** correct how is it **changed**?

5. What is the value of the **time indicator** on the display or a screen print?
Questions (continued)

6. If the “no data” indicator is displayed adjacent to the MPH and RPM indicators, what is your plan of action? Explain.

7. If the vehicle requires a manual gear selection, how is it indicated on the display?

8. What is the key to enter the gear selection display?

9. What is the key required to change the vibration source indicators (selected component)?

10. Why do some vehicles require gear selection while others do not?

11. What is the default gear selection if none is selected?

12. What effect will using the default gear position have in diagnosis?

13. Which active key changes the three NVH Data displays?

14. How many events are displayed on the barchart and 3d display?

15. Which line is the most recent event on both the:
   - barchart
   - 3d display
Questions (continued)

16. On the barchart display, is the total dBG displayed:

A. the sum of the engine, driveline, and wheel dBGs

B. or the greatest level of total vibration felt in the vehicle (engine, driveline, and wheel levels are compared to the total)

17. How do you change the amplitude scale factor on the barchart display?

What is the range?

18. What is the function of the RCV key?
Description:  **NVH Data Analysis**

NVH data analysis is the key to using the NVH Analyzer in the diagnostic process. The ability to accurately identify the "spikes" associated with the vibration, causing the customer complaint, will contribute to your success and customer satisfaction.

The NVH training simulation software contains pre-recorded vehicles with typical vibration characteristics and customer complaint vibrations. Specific scenarios are selected by choosing one of the following vehicles on the vehicle select screen.

- 93 Truck 3VZ-E 4WD G254 AT STREAM 31
- 93 Truck 3VZ-E 4WD G254 AT STREAM 73
- 93 Truck 3VZ-E 4WD G254 AT STREAM 76
- 93 Camry 5S-FE AT STREAM 35
- 93 Camry 5S-FE AT STREAM 72
- 93 Landcruiser STREAM 30

The NVH data analysis worksheet is designed to utilize the NVH training software to provide practice analyzing vibrations. The software allows this activity to take place in the classroom where everyone can benefit from the same scenarios, discussions and direction from the instructor.
Instructions

1. **Install** the NVH training simulation software and go through the function and **vehicle selection menus**. Use the skills developed in worksheet #3A.

   **NOTE**

   Follow the directions from your instructor in selecting the vehicles. The directions will include details from the **customer interview sheet** and the **symptoms classification flow chart**.

2. **Observe** the data displayed on each of the three displays. Use the skills developed in worksheet #3B to **manipulate** the screens to observe the **clearest view** of the data.

   For example:

   Changing the amplitude to a higher scale may eliminate vibrations that are normal. Changing the frequency range may make low frequency wheel vibrations easier to read.

   **NOTE**

   The scenarios were recorded for the length of time required to capture a **representative sample**. The software will display the data in a **continuous loop**. **Watch** the RPM and MPH indicators to determine the beginning of the loop.

3. Select each of the three source indicators and **identify the spikes** above each arrow on the 2d and 3d displays.

4. **Compare** what is indicated on the 2d and 3d displays to the data indicated on the barchart display.

5. When you have **identified** the spike that is associated with the symptom perform a **save and screen print** of all the displays. Attach to the sheet provided.

6. **Formulate a plan** for a thorough **road test** that you would perform to determine if your conclusions are correct. Base the plan on the information from:

   - the customer interview sheet
   - the symptoms classification flow chart
   - the data viewed in the scenario

   Place your answer in the space provided on the attached sheet.

   **NOTE**

   The ability to **anticipate** what spikes you should find is very helpful in diagnosis. It makes it easier and more efficient to plan the display manipulations and the road test.

7. Answer the questions as you review the scenarios and place your answers for 1-10 on the **chart** (attached).

Questions

1. Based on the information from the customer interview and the symptom classification, indicate what **type of vibration** you expect to see on the display prior to reviewing the NVH data.

   - engine 1st order 2nd order 3rd order 4th order
   - driveline 1st order 2nd order 3rd order 4th order
   - wheels 1st order 2nd order 3rd order 4th order
Questions (continued)

2. Observing the spikes in question, what frequency range would best display the spikes? Explain.

3. While viewing data on the 2d display, are there any spikes shown at frequencies greater than 125 Hz?

4. What amplitude range will clearly display the larger spikes and eliminate the normal vibrations?

5. Which scenarios indicate an overlap condition?

6. Which indicators are overlapping?

7. What would your plan of action be for a road test to determine which source was causing the spike? Be specific.

8. Which source shows the greatest level of energy on the barchart display?

9. After reviewing the displays which are the vibrations of concern?

10. What are your conclusions and plan of action from the symptom information and NVH data on this vehicle?
Conclusion

1. Why were the three sources of vibration (engine, driveline and wheel) selected for indication by the NVH Analyzer?

2. When is a comparison of amplitude level from vehicle to vehicle of little value?

3. What is the value of recording the amplitude level of the vibration causing the complaint before the repair?

4. How do you obtain the exact frequency and amplitude of any spike displayed?

5. What is your plan if you find a significantly large spike that is not over an arrow?

6. What type of vibrations and sounds are the technician expected to repair? Give examples.

   Explain.

7. What type of vibrations and sounds are beyond the scope of the technician? Give examples.

   Explain.
Questions (continued)

8. What is the value of the diagnostic procedures and the NVH Analyzer when dealing with vibrations that require assistance?

9. List the information necessary prior to calling for assistance.

10. On the Stored Data Blocks screen which is the most current stored data and where is the default position of the cursor?

11. How many data blocks can be stored? What are the active keys required to store data?

12. What happens if you hit ENTER to save paused data and the all the blocks are full?

13. When do you get the “Review Old Data” screen? Under what conditions does it appear?

14. What are the two ways to delete data saved?

15. What is missing when analyzing data on the training software compared to analyzing data during the Road Test?
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<th>QUESTION</th>
<th>1. ANTICIPATED VIBRATION SOURCE/ORDER</th>
<th>2. BEST FREQUENCY RANGE</th>
<th>3. “SPIKES” ABOVE 125 Hz YES/NO</th>
<th>4. BEST AMPLITUDE RANGE</th>
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<td>dBg</td>
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<tr>
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<td>dBg</td>
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<tr>
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## NVH Diagnostic Procedures

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<th>5. OVERLAP YES/NO</th>
<th>6. INDICATORS</th>
<th>7. PLAN OF ACTION</th>
<th>8. BARCHART LEVEL</th>
<th>9. ACTUAL VIBRATIONS SOURCE/ORDER</th>
<th>10. CONCLUSIONS PLAN OF ACTION</th>
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**SYMPTOM 2**

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Diagnostic Description: **Dynamic NVH Data Analysis**

The NVH training software used in worksheets #3A, #3B, and #3C provide excellent classroom training to introduce and develop basic skills with the NVH Analyzer.

This worksheet is designed to add the dynamic element of sensing the vibration or noise while analyzing the NVH data. Sensing the symptom while viewing the data develops the relationship between the vibration or noise and the spikes. The ability to make this relationship is key to duplicating and manipulating the symptom which will make diagnosis easier.

**Instructions**

1. **Install** the NVH/BREAK-OUT BOX Program Card.

2. Connect the **Data Link Cable** and the **Accelerometer** to the vehicle set up in the shop, using the Operator’s Manual.

3. **Review** the information from the Customer Interview Sheet and the Classification Flow Chart for the vehicle selected.

4. Use the skills gained in worksheet #3C to anticipate and develop a plan to analyze the data.

5. With the help of the instructor confirm the customer complaint in the vehicle set up in the shop.

6. **Analyze** the data while duplicating and manipulating the symptom, save and print a representative sample of each display. Attach to the sheet provided.

7. Based on the complaint information and the NVH data analysis, develop a plan for a pinpoint diagnosis.

8. **Remove** the “bug” and retest the vehicle to confirm the “repair”. Attach a screen print to sheet provided.

**Questions**

1. What are your conclusions from the NVH data analysis for developing a pinpoint diagnosis plan?

2. **List** the advantages of being able to sense the vibration or noise while analyzing the NVH data.
Questions (continued)

3. How does sensing the symptoms make the diagnosis **more efficient** than simply viewing the data in worksheet #3C?

4. After the “bugs” were identified would you have come to the **same** conclusions or a pinpoint diagnostic plan in question #1? Explain.
<table>
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</table>
Learning to associate the NVH data with vehicle vibrations takes practice and an understanding of how the different displays provide information. It is also helpful to understand how the displays can be compared to one another to isolate the data that relates to the complaint.

**NVH Analyzer Displays**

Fig. 2-15

- **Diagnostic Display Interpretation Hints**

  “VIBRATION” function
The road test techniques are also valuable when using an NVH analyzer while trying to isolate a complaint. Duplicating and controlling the symptoms during a road test can help identify specific data that responds in the same way as the symptom.

For safety reasons, the pause and save (F0 F6) features are helpful to store and review the data after the road test. It is very difficult to safely operate the vehicle and analyze data at the same time. A second person to operate the vehicle is also useful during a road test, especially if the vibration is intermittent.

For example:

The 2d display (which is a two dimensional display that plots the vibrations according to frequency and amplitude) is useful during the test drive of an engine vibration. The driver can shift the vehicle into neutral and coast while the technician watches or records the vibrations. The spikes on the display that are related to the engine should go away while the spikes that are related to the driveline or wheels should remain.

The barchart display is a three dimensional display that shows eleven samples of data, plotting the amount of energy of the vibrations in the three source groups:

- Engine
- Driveline
- Wheels and tires

The barchart display makes an excellent starting point for diagnosis. It is very helpful to determine where the most amount of energy is generated or how the energy is distributed.

A technician can decide which of the above areas to focus on when moving to the 2d or the 3d displays for more specific analysis of the vibrations.

For example:

While test driving a vehicle, the barchart display may show the majority of the energy in the area of the driveline. The technician can now switch to the 2d display (F1), select the driveline indicators (F3), and look for large spikes that fall above the driveline arrows. Large spikes would indicate vibrations that would generate the high energy levels on the bar chart display.
A large spike above a **driveline arrow** would confirm a driveline condition. The amplitude level can be **documented** for future reference. A technician can now focus the diagnosis in the driveline area.

The NVH Analyzer is designed to do the math required to associate a specific frequency vibration with one of the three groups listed above. It displays this by providing the terms “engine”, “driveline” or “wheels” on the display and arrows for various order vibrations. These arrows are placed below the display pointing to the associated frequencies. A “^” is used to depict the CV joint frequency when checking driveline vibrations.
“VIBRATION” function

When using the NVH Analyzer it is very important that the **vehicle parameters** be verified for the vehicle being tested. Every effort has been made to provide an accurate data base but there are many variables and combinations involved with our vehicles.

### Vehicle Parameters Menu

**Fig. 2-17**

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<td>Engine Type V6</td>
</tr>
<tr>
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</tr>
<tr>
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<tr>
<td>Data Source CHK</td>
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<tr>
<td>Drive Type RWD</td>
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</tbody>
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**NOTE**

Location for Data Link Cable

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**Sticker on “B” Pillar**

**Fig. 2-18**

MFD. BY: TOYOTA MOTOR CORPORATION 10/91
GVWR 3370LB GAWR FR 2281LB RR 1950LB
THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE SAFETY, BUMPER, AND THEFT PREVENTION STANDARDS IN EFFECT ON THE DATE OF MANUFACTURE SHOWN ABOVE.
JT2SW21N3N000001 PASS.CAR
C/TR: 742/FF22
A/TM: 692/S54
MODEL: SW21L-AJMZKA
MADE IN JAPAN
NO.728 BA01511077

---

Production Date

---

Axle Code

Transmission Code
It is possible to have a unique situation that requires research in the Repair Manuals, parts fiche, TSBs and NCFs to collect the specifications necessary to modify the data base.

When the data base is accurate, the arrows will properly line up with engine, driveline and wheel vibrations.

An LED will light and "overlap" will flash when there is a possible overlap situation. This indicates that more than one source needs to be considered for a vibration displayed on the screen. The arrow will also flash indicating which spike could be caused by more than one source.

For example:

When a vehicle is operating in fourth gear on a manual transmission it is possible for the gear ratio to be 1:1. The engine speed and the driveline speed are the same in this case, therefore an overlap could occur with a vibration generated by either area.

In this case an LED will light warning the technician of the overlap condition. The technician would view the other two groups ([ ] ) to identify the overlap. This is done by finding the spike that has an arrow pointing to it in more than one area (engine, driveline, wheels).

In this example, the technician could select a different gear or step on the clutch to make the engine and driveline RPM different. This would isolate the vibration to a specific source.
The **3d display** provides a three dimensional (3d) view of the vibrations in a vehicle by displaying 11 spectral lines (2d) which provides **a brief history of the vibrations**. Each of the **eleven lines** is the same as one 2d line, showing frequency and amplitude. By stacking them, a technician can easily observe **changes** in the spikes as the symptom changes.

This is helpful when road testing a vehicle with a difficult condition to diagnosis. When the technician modifies the operating conditions of the vehicle, while trying to control the symptoms, the 3d display will show changes in the spike related to the complaint. Observing which spike changes as the symptom changes can identify the area causing the condition by looking at the arrow associated with that spike.
“VIBRATION” function
Continued

For example:

If you watch the normal engine firing vibrations on the 3d display, you will note a variation in the amplitude of the vibration due to power fluctuations of the engine. The power fluctuations are caused by changes in the air/fuel ratio in a normal feedback system.

Each of the displays can be changed to customize the parameters and focus in on a sample. These features allow the technician to eliminate data that is not applicable and provide a clearer view of the data that is relevant to the condition.

The parameters can be changed in the following way:

- Frequency band width (F2) forward & (F3) backward
- Floor and ceiling level of the amplitude scale (F3)
- Engine, driveline and wheel indicators (F3)

**Frequency band width** is adjustable to the following four ranges using the F2 key:

- 0 - 500 Hz
- 0 - 250 Hz
- 0 - 125 Hz
- 0 - 62.5 Hz

The frequency band width defaults to the 125 Hz scale when the display is first selected from the vehicle parameters menu. Once in the display, if a different scale is selected, then it remains at that level as other displays are selected.

The scale selected is shown in two places on the 2d and 3d display as shown in fig. 2-21 and in the upper right corner of the barchart display.

The advantage of starting with the 125 Hz scale is that it gives a clear view of the spikes most likely generated by a vehicle. Once a spike or range has been identified, the appropriate band width can be selected using the F2 key. If the default is set at a smaller frequency band then a spike outside that range may be overlooked. A quick check of the 500 Hz scale will reveal any spikes that may appear above the default setting.

If there is an indicator arrow outside the frequency band selected, there will be a flashing LED and frequency indicator to warn the technician to check a larger frequency range for possible spikes.
The **floor and ceiling level of the amplitude scale** is adjustable from the default position of **10 to 30 dBg** range with the \( \uparrow \downarrow \) keys. The following ranges are available:

- 0 - 20 dBg
- 10 - 30 dBg
- 20 - 40 dBg
- 30 - 50 dBg
- 40 - 60 dBg

The advantage of moving the amplitude window is to **drop out of view spikes that are normal** in a particular vehicle, leaving the larger amplitude spikes for analysis. The display becomes less confusing and easier to interpret.

---

**Default Settings for Frequency and Amplitude**

![Diagram](Fig. 2-21)
Additional display features include:

- RPM and MPH display
- Time display
- Cursor w/Hz and dBg (\(\text{\textcopyright}{\textstyle \triangledown} \text{\textcopyright}{\textstyle \triangledown}\))
- “NO data” indicator for RPM/MPH

The RPM and MPH are displayed in the upper left corner of the screen. This data is collected from the data link connected to a diagnostic connector identified in the vehicle parameter screen.

Many NVH complaints are related to RPM or vehicle speed. The display makes it convenient to monitor RPM and MPH from the check connector or data stream without additional test equipment.

There are two ways the tool obtains the data for RPM and MPH. The first is from the data stream on late model vehicles and the second is from the IG- signal on non-data stream vehicles. The tool is able to determine where to get the information when the vehicle is selected by the technician. The vehicle parameters screen has a line indicating the connector that has to be used. In addition, an asterisk is displayed next to the MPH indicator when gear selection is required by the user.

The tool is not able to determine the gear selection when using IG-. The technician needs to press \(\text{\textcopyright}{\textstyle F_8}\) and select the gear manually for the driveline and wheel indicators to be accurate.
The default position for the gear selection is the highest transmission gear available and will be accurate when driving in that gear if a selection \( F_8 \) was not made.

Other differences between using the data stream and IG- include:

- The resolution of RPM on IG- is an actual reading, on the data stream it changes in 25 RPM increments.
- On IG- vehicles when the RPM is below 1600 the MPH reads 0.

RPM and MPH will be displayed if:

- The vehicle is equipped with functioning IG- in the under hood DLC1 (check connector)
- Data stream is available from the DLC1 (check connector), DLC2 (TDCL), or DLC3 (OBD2 connector)
- All connections are complete from the check connector to the NVH Analyzer
- The NVH Analyzer is functioning properly

“NO data” indicator for RPM/MPH is a feature that appears to let the technician know that there is no communication through the data link.

When a vehicle has both IG- and a data stream, the data stream should be used for accuracy. Check for a DLC2 (TDCL) or DLC3 connector and use it if available.

When using DLC2 (TDCL), the NVH Analyzer must be connected to the cigarette lighter for power. There is no B+ terminal in the DLC2 connector.

The time display provides the screen print with a time stamp which helps differentiate and sequence multiple printouts. It helps eliminate questions as to whether a printout applies to a specific vehicle or road test event.

A cursor is available with the use of the keys which allows the technician to find the exact frequency and amplitude of a particular spike. This is done by placing the cursor directly over the spike and reading the frequency and amplitude above the display. The indicators move with the cursor.

The cursor moves in equal increments with each stroke of the key or progressively faster if the key is held. If the end of the display is reached then the cursor automatically appears at the opposite end of the display.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Increment</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>4 Hz</td>
</tr>
<tr>
<td>250</td>
<td>2 Hz</td>
</tr>
<tr>
<td>125</td>
<td>1 Hz</td>
</tr>
<tr>
<td>62.5</td>
<td>.5 Hz</td>
</tr>
</tbody>
</table>
The noise selection from the main menu will function the same as the vibration selection. The menus for vehicle setup are the same and the noise function uses the same diagnostic displays. The exception is in the parameters for amplitude.

- dB is used instead of dBg
- The floor and ceiling level default is 65 to 85 dB
- The following ranges are available:
  
  45 - 75 dB
  65 - 85 dB
  75 - 95 dB
  85 - 105 dB
  95 - 115 dB

A microphone is used instead of an accelerometer as an input for sound. The microphone is non-directional and cannot be used to find the location of a noise.

Noise function operates the same as the vibration function because a noise is also a vibration. The same skills used to isolate a vibration are also used with noise.

It is important to understand that noise can also be generated by:

- Rattles
- Squeaks
- Wind

These are in addition to noises that can be generated by the three component groups indicated by the arrows on the displays:

- Engine
- Driveline
- Wheels and tires

Rattles, squeaks and wind noise will be discussed in the last part of Section 4 and in the Wind and Interior Noise program. The techniques used to diagnose these areas are different than noises related to the three major sources that the NVH Analyzer is able to display.

Rattles are usually low frequency, low amplitude and intermittent making them difficult to identify on a vibration analyzer.

Squeaks and wind noise are usually high frequency above the 500 Hz limit of the NVH Analyzer.

Other noises of significant amplitude, which are within the NVH Analyzer frequency limits, can be displayed on either the vibration or the noise selection.
The classification process discussed earlier is very helpful in identifying the frequency range of a noise to determine which diagnostic technique is most appropriate:

- For frequency ranges below 500 Hz, the NVH Analyzer can identify one of the three sources of vibration: engine, driveline, wheels.
- For frequencies above 500 Hz, a pinpoint diagnosis for rattles, squeaks or wind noise should be used.

The ability to control the noise, through test driving techniques, can produce a relationship between the noise and the spike displayed on the NVH Analyzer.

For example:

If a noise appears at a specific speed or operating condition then the technician needs to become familiar with the data displayed when there is no noise. When the noise appears then the spike that was not there before should be identified. If the spike appears above a pointer associated with a component group then diagnosis should be directed in that area.

If the frequency of a vibration or noise spike is not associated with an arrow, then the frequency should be multiplied by 60 to find the RPM. The components operating at that RPM can be considered for diagnosis.

The skills developed in using the NVH Analyzer are now applied in the next area of diagnosis, the road test.

Road Test Procedures

Install NVH Analyzer to monitor and record NVH and vehicle data
(See NVH Analyzer operating and instruction manual for details).

A tachometer is recommended if a NVH Analyzer is not available and the vehicle is not equipped with a tach. MPH can be noted from the speedometer.

A road test course should be selected that allows for safe operating conditions that will duplicate the customer’s complaint. Frequent use of the same course will allow the technician to develop experience in predicting what normal vibrations can be expected during different aspects of the road test.

Known good vehicles should be analyzed on this course for comparison with complaint vehicles. This will be most helpful when looking for spikes, related to complaints, on a NVH Analyzer display.
Engine Run-up Test

After installing the NVH Analyzer, use the engine run-up test to determine if the complaint is related to engine speed or vehicle speed.

With the information from the interview sheet, and the complaint verification, try to duplicate the symptom by creating the same vehicle and operating conditions described by the customer.

Start at idle, cold or hot, (if applicable) then increase the engine RPM with the transmission in Park or Neutral.

If the symptoms occur, record the vibration to capture the engine RPM, frequency and amplitude of the complaint for future reference. Further road test procedures are not necessary.

If a vibration occurs, but does not directly relate to an engine vibration indicator, then an accessory such as power steering, A/C, or water pump should be considered.

These components operate at different speeds/frequencies relative to the pulley diameter. Using the calculations outlined in Section 1 and a photo tach, you can identify the accessory that is related to a spike on the NVH display.

Shifting the vehicle into neutral when the symptoms occur will also help confirm if the complaint is engine or vehicle speed related. If the vibration goes away as the engine RPM goes to idle, further diagnosis in the engine area is required.

Brake Torque Test

Some engine related vibrations may be sensitive to load. Block the wheels, set the brakes and raise the engine RPM with the transmission in drive. This will apply a load on the vehicle which may cause components to move and vibrate, that would not under normal operating conditions. Use the 3d screen to easily recognize unusual or different vibration.

For example:
- motor mounts
- exhaust system contact
- engine misfire

CAUTION

Use care not to overheat the engine or transmission.

Light Acceleration Test

If the above tests do not duplicate the complaint then perform the light acceleration test. Accelerate on a smooth, level surface until the symptoms are present. Record the vibration at the point when it is most noticeable.

Note if the vibration changes or disappears when cruise is maintained, after acceleration. If it occurs perform a heavy acceleration to see if the condition can be exaggerated.
Some conditions require the vehicle to be under load, for example, a propeller shaft vibration. Heavy acceleration and/or a road test course that includes a hill will be helpful to provide the load required to duplicate the complaint.

For example:

Loading and unloading a driveline is very helpful in isolating a propeller shaft condition, especially when there is an overlap indicated on the NVH Analyzer for driveline and wheels. As the driveline loading changes a propeller shaft vibration will change. A condition in the wheel area will tend to stay constant.

An overlap indication is indicated on the NVH Analyzer with the word “overlap” displayed on the screen and an LED light below the screen. When this occurs, the technician should change the vehicle condition to eliminate the overlap and observe the spikes that remain.

Some engine related vibrations, transmitted through the exhaust, are also more noticeable under load than during an engine run-up test.

Cruise is often the most common operating condition of a complaint. It is much easier to “tune” into a particular symptom when it is continuous.

In addition to constant vibrations, beating vibrations that come and go need to be observed during cruise over a longer period of time. A noticeable beat may occur in 4-6 second cycles.

Although the customer may indicate that the vibration occurs at a particular speed, the road test should include several cruise speeds, (i.e. 35, 45, 55 MPH). The speed the customer mentions may be the most common operating speed and not the speed that produces the greatest amplitude.

For example:

Tire vibrations are often most noticeable when they resonate with the suspension or steering system between 40 and 55 MPH. Driveline vibrations are often more noticeable at speeds above 50 MPH.

A road test should also include some rough road to induce energy into the suspension that may produce vibrations or shimmy in the steering wheel.

For example:

A leaking front strut will cause a suspension and steering system to resonate on a rough road.

Rough road conditions may also produce noises such as squeaks or rattles that are not as noticeable on a smooth road.
Coasting  The advantage of coasting is that it **eliminates engine vibrations** and **load**. The vehicle environment may become quieter making it easier to notice noises that are **masked** by other sounds.

Deceleration  Deceleration is similar to coasting with the **addition of load** caused by engine compression. The load is a different force then load applied during acceleration. This will cause components to react differently under these conditions, producing a larger level vibration.

Turning  CV joint symptoms often appear in a turn when the joint angle increases. In many cases, the NVH Analyzer will show an overlap with a third order wheel vibration. Putting a load on the CV joint may **increase the level of the vibration**, while the third order wheel level would remain the same.

Turns are also helpful in identifying vibrations from components **which contact the body**. **Worn suspension parts** may shift with a side load.

The customer interview sheet can be very helpful to identify the need for this type of test.

Jounce Test  A technician may be able to reproduce a noise by simply **bouncing the vehicle up and down**. It should be done at each quarter of the vehicle while observing components and listening for sounds. A second person is helpful during this test.
**Additional Road Test Considerations** When the symptom is at its most noticeable level, the technician can try to **control or modify the symptoms** to help isolate the source. The following chart is a list of additional items to keep in mind while trying to diagnose a complaint. You may add items as you gain experience with NVH diagnosis:

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicles w/o locking torque converters</td>
<td>A few of our vehicles do not have locking torque converters. The NVH Analyzer calculates MPH using RPM and the gear ratio data base. In these cases it is important to make sure the vehicle is <strong>not</strong> under load and that stable cruise has been established for accurate driveline and wheel arrow indicators.</td>
</tr>
</tbody>
</table>
| Brake application | Lightly applying the brake at cruise may produce a vibration at wheel speed frequency. Pedal feel is important during this procedure.
Lightly applying the parking braking will do the same as the above but only to the rear wheels. This can be helpful in isolating a front or rear brake condition.
Caution: Use care not to overheat the brakes in this procedure. Damage and additional vibration may result. |
| 4x4 vehicles | 4x4 vehicles have additional driveline components that may be engaged, disengaged or removed to determine which group is contributing to the complaint, |
| Accessories | Turning accessories on and off may also have an impact on the symptoms. They may cause a belt to resonate or slip. This test may also effect an accessory condition caused by a worn bearing, mounting or slipping A/C clutch. |
| Electric cooling fans | Cooling fans often require a specific temperature level to engage. A fan imbalance or runout condition may only be identified when the fan engages at that temperature. |
| Power steering | Symptoms relating to power steering may be temperature related. These conditions may only be present with the system under load. For example: a vibrating high pressure hose caused by incorrect mounting or routing. |
Alternative Diagnostic Methods

Although the road test or a dynamometer is ideal, and sometimes the only way to duplicate a customer complaint, the use of a lift or safety stands can also be helpful for diagnosis.

In order for this technique to be safe and effective, the following details must be considered:

- **Verification** of the customer complaint is very important to determine when diagnosis without a road test will produce the symptoms. Not all complaints can be duplicated without setting up the same vehicle and operating conditions. For example, the ability to apply a load to a system.

- To duplicate many driveline and suspension complaints the vehicle has to be raised maintaining the correct operating angles.

New vibrations may occur on a lift that do not exist on the road. This is due to the change in loading of the suspension and possible interaction of the vehicle with the lift. The lift is now carrying the weight of the vehicle not the tires and wheel bearings.

**Balance is critical** in safely operating a vehicle in a shop. Normal vibrations may cause a vehicle to move out of position or fall.

- Operating one drive wheel while the other is stationary is a technique used to isolate a symptom. The front wheels on a FR vehicle or the rear wheels on a FF vehicle cannot simulate operating movement and will not contribute to the vibrations in a vehicle. This can be helpful if the vibration complaint that was verified goes away.

It is important to remember that the wheel will rotate at twice the speed indicated on the speedometer, due to the differential.

For example:

If the speedometer is indicating 40 MPH and one drive wheel is stationary while the other is turning, then the turning wheel is rotating at 80 MPH.

If the stationary wheel is on the ground the vehicle could move causing severe damage. This is especially true in vehicles with limited slip differentials.

**Traction Control** must be turned off on vehicles so equipped. Due to the differential in wheel speed the system will activate.

The advantages of this type of diagnosis include:

- The ability to perform a good visual inspection while the vehicle is operating. For example, observing runout of a wheel or tire.

- The ability to use tools such as a stethoscope or a screw driver to amplify a vibration on specific components.
Diagnostic Description: **Road Test with the NVH Analyzer Vibration Function**

The road test is a diagnostic procedure designed to duplicate and manipulate the symptoms in order to gain as much additional knowledge as possible. This knowledge will help identify the source of the symptom by a process of elimination.

This worksheet is the third in the series of worksheets that is used to diagnose the conditions placed in the shop vehicles by your instructor.
**Instructions**

1. The technician should use all the information collected during the Verification of the complaint (worksheet #1) and the Classification Flow Chart (worksheet #2) to establish a road test plan that is most likely to duplicate the symptom/s. The symptom/s can then be manipulated and measured with the NVH Analyzer. (Refer to Section 2 of the technician handbook.)

2. Consider the possible sources of the complaint from the information in step #1 and develop a strategy for analyzing the NVH data during the road test.

3. Connect the NVH Analyzer to the vehicle, perform the road test and save the data relating to the symptoms.

4. Take notes regarding the road test procedures and results for review with the saved data.
   
   For example:
   
   Note if the symptom was most noticeable in a left turn on a hill. The analyzer will display MPH and RPM but cannot tell you the additional information about the road test that you may have performed to duplicate the symptom. With several possible saved samples you may become confused without good notes.

5. Review the data saved on all the displays using the skills developed during NVH data analysis worksheets #3A, #3B & #3C.

6. Identify the spikes on the 2d and 3d displays that are associated with the symptoms and compare the conclusions with the data on the barchart display.

7. Determine the source of the symptoms, including the order, that will be the focus for the pinpoint diagnosis.

8. Print the screens and attach with the space provided to support your conclusions.

9. Add the notes from the road test that will help identify the source of the complaint and the pinpoint diagnosis area.

10. Compare your results with the plan you formulated in step #1 and #2.

11. Remove the “bugs”, retest and compare your results. Attach screen print to the space provided.

**Questions**

1. List the road test procedures you plan to use to measure and duplicate the complaint.

2. What is the advantage of making the road test plan prior to performing the test?

3. What page in Section 2 did you find the details of the road test?

4. Outline the strategy you plan to use to analyze the NVH data during the road test.
5. **Where** did you connect the **data link cable** to the vehicle?

6. How did you determine this **location**?

7. **Where** did you locate the **accelerometer** and why?

8. List **two** items that are important to consider when **positioning** the accelerometer. Explain each.

9. **How many people** should be involved in a road test and why?

10. **How many events** should be saved and why?

11. What are **two** advantages of taking the **printer** along for the road test, if available?

12. **How many large spikes** are displayed on the 2d display?
13. **Record** the frequency and amplitude of the **significant** spikes on the chart below.

<table>
<thead>
<tr>
<th></th>
<th>FIRST ORDER</th>
<th></th>
<th>SECOND ORDER</th>
<th></th>
<th>THIRD ORDER</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freq/Ampl</td>
<td></td>
<td>Freq/Ampl</td>
<td></td>
<td>Freq/Ampl</td>
<td></td>
</tr>
<tr>
<td>ENGINE</td>
<td>/</td>
<td></td>
<td>/</td>
<td></td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>DRIVELINE</td>
<td>/</td>
<td></td>
<td>/</td>
<td></td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>WHEELS</td>
<td>/</td>
<td></td>
<td>/</td>
<td></td>
<td>/</td>
<td></td>
</tr>
</tbody>
</table>

14. What is the **incremental movements** of the cursor on the:

- 62.5 Hz scale __________
- 125 Hz scale __________
- 250 Hz scale __________
- 500 Hz scale __________

15. What happens to the **cursor** if you **hold** your finger on the key?

16. On the **barchart** display which component sources indicate a large level of vibration/energy?

17. **Manipulating** the vibration during the road test can be seen **best** on which display? Explain.

18. Which display would show a **beating symptom** the best? Explain.

19. What is the **next display** you would look at once a beating symptom has been observed in question 18? Explain?

20. Which vibration **changes** frequency when **different gears** are selected with a **constant vehicle speed**?

21. What are the advantages of the **time indicator**? Explain.
Conclusion

1. Based on the information used to set up the road test and the data from the NVH Analyzer, what is your **plan of action** for the **pinpoint diagnosis**?

2. Did you notice an **improvement** in the vehicle condition after the “bugs” were **removed**?

3. Did the NVH Analyzer **indicate** an improvement? How much?

4. Upon **discovering** the “bugs” was your **plan** for pinpoint diagnosis **on track**? Explain.
<table>
<thead>
<tr>
<th>2D</th>
<th>BARCHART</th>
<th>3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATTACH SCREEN PRINT HERE</td>
<td>ATTACH SCREEN PRINT HERE</td>
<td>ATTACH SCREEN PRINT HERE</td>
</tr>
<tr>
<td>AFTER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATTACH SCREEN PRINT HERE</td>
<td>ATTACH SCREEN PRINT HERE</td>
<td>ATTACH SCREEN PRINT HERE</td>
</tr>
<tr>
<td>COMMENTS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Diagnostic Description: **Road Test with the NVH Analyzer Microphone Function**

The microphone (optional) is added to the Toyota Diagnostic Tool Set to assist in diagnosing noise complaints. It uses the same menus, displays and key strokes as the vibration function.

This worksheet is designed to demonstrate the functions of the noise analyzer with the microphone.
Instructions
1. On the same vehicle you diagnosed in worksheet #4A, connect the NVH Analyzer with the microphone and select the NOISE function on the NVH MAIN MENU.

2. Road test the vehicle duplicating the symptom and review the data on all the displays.

3. Move the microphone around the vehicle and note any changes.

4. Save representative displays that provide the clearest view of the spikes associated with the complaint.

5. Print each display and compare them to the print outs captured in worksheet #4A. Attach screen print to the space provided.

Questions
1. Are there any differences in the menu structures, key strokes or displays? Please list.

2. What frequency ranges are available for diagnosis?

3. How is the amplitude measured?

   What are the ranges?

4. When the microphone was moved around the vehicle did you note any significant change?

5. What conclusions can you draw about the use of the microphone in finding the location of a noise?

6. Where is the best location for the microphone for noise diagnosis?

7. What types of noises can be diagnosed with the microphone? Explain.
8. What type of noises cannot be diagnosed with the microphone? Explain.

9. How would you resolve noise complaints that are not diagnosed with the NVH Analyzer?
   Where do you get the information?

10. What are the similarities between the microphone and the accelerometer for diagnosis?

11. What principle in Section 1 of the text explains the phenomenon in question 10?
<table>
<thead>
<tr>
<th>2D</th>
<th>BARCHART</th>
<th>3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATTACH SCREEN PRINT HERE</td>
<td>ATTACH SCREEN PRINT HERE</td>
<td>ATTACH SCREEN PRINT HERE</td>
</tr>
<tr>
<td>AFTER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATTACH SCREEN PRINT HERE</td>
<td>ATTACH SCREEN PRINT HERE</td>
<td>ATTACH SCREEN PRINT HERE</td>
</tr>
<tr>
<td>COMMENTS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary

At this point in the diagnosis, the technician has used the following to classify the complaint:

- Interview sheet
- Flow chart
- Road test with NVH Analyzer

The classification process has reduced a large list of possible symptoms to just a few which fit the complaint.

The technician can now use the specific characteristics associated with the symptom to perform the pinpoint diagnosis, which will be the subject of the next section. (See Section 1 details on the characteristics associated with a specific classification)

Case Study: Part III

The interview sheet was used to choose the following road test from the procedures outlined on the road test reference card:

- 40 - 60 MPH
- Cruise

The NVH Analyzer “Vibration Selection” was used during the road test to capture the data. The technician selected the vibration function because the complaint was described as a vibration and a noise. We know that a noise is also a vibration which can be displayed on the tool. (Section 1)

The displays shown were selected based on the information gathered during the verification of the complaint.

- Barchart display shows the largest amount of energy divided between the wheel and driveline areas, with very little energy visible in the engine area.
- 2d display shows two large spikes in the 125 Hz frequency range.
  - The default frequency band (125 Hz) clearly displays the two spikes in question
  - The default amplitude window eliminates spikes that may normally appear in a 4Runner
  - The cursor is moved over the spikes in question to display the exact frequency and amplitude
  - The F3 key is toggled to see if the engine, driveline or wheel arrows line up with the spikes
  - Two displays are captured and printed for future reference, because at 55 MPH the 12 Hz frequency spike lines up with the wheel arrow and the 54 Hz frequency spike line up with the driveline arrow. This information supports the data shown on the barchart display.
The data indicates that there are two possible conditions contributing to the complaint. One in the area of wheels and the other in the area of driveline.

The road test eliminated the engine as a source of the complaint and maximized the symptoms for measuring.

The next section will deal with the pinpoint diagnosis of the steering shimmy and the body booming in the driveline and wheel areas.
Lesson Objectives

1. Demonstrate the ability to select a pinpoint diagnostic procedure that is appropriate for the conditions identified during the NVH diagnostic procedures.

2. Demonstrate the ability to perform a thorough visual inspection.

3. Demonstrate the ability to use the pinpoint diagnostic charts to assist in selecting the appropriate procedures.

4. Demonstrate the ability to select and perform the proper repair that will ensure long term customer satisfaction.

5. Determine when it is appropriate to call for technical assistance.

6. Be able to list the information necessary for a quick resolution to the problem, prior to contacting technical assistance.

7. Demonstrate the ability to verify the complaint has been resolved.
**Introduction**

The pinpoint diagnosis section focuses on the procedures required to **identify the specific condition** causing the complaint. It will also, in many cases, identify the **solution** to resolve the condition. Situations that require additional procedures to repair the condition are covered in Section 4.

At this point in the diagnosis, the technician knows the **symptom** that is associated with the complaint and the **source** of the complaint.

This part of the diagnostic section will deal with isolating the **component or condition** relating to the complaint. It is organized by **source group** (same as the NVH Analyzer), dealing with the most common condition associated with each classification in that source group.

**Visual Inspection**

Throughout this course we have been discussing NVH in relationship to the senses. It only follows that the **senses** are one of the technicians greatest **assets** in resolving NVH conditions.

Throughout all aspects of diagnosis the technician should:

- Look
- Listen
- Feel

A thorough **visual inspection** can provide the technician with clues or even reveal the condition causing the complaint. Observations can uncover:

- Vehicle damage
- Previous service
- Broken, loose, missing or worn components
- Aftermarket installations
- Tire wear or damage

Examples include:

- An aftermarket exhaust system that is not built to the same specifications as an OEM systems. These types of parts can produce drones or body contact which will show up on the NVH Analyzer as an engine related vibration.
- A trailer hitch installation that produces a transmission path to the interior of the vehicle.
- Mass or dynamic dampers that have been removed for a service procedure and not put back on the vehicle.
- A reinforcing bracket between the engine and the bell housing left off during a previous service.
- A bell housing which has not been properly torqued.
During a visual inspection, a **stethoscope or a screw driver** can be used to **amplify** a vibration from a suspect component and relate it to the complaint vibration.

Examples include:

- Lightly holding a screw driver on the metal support of a vibrating headrest. The resulting tapping noise can be associated with a frequency range. Knowing the frequency would help the technician identify the source of the vibration.

- Lightly holding a screw driver on components such as an exhaust system or suspension will amplify a vibration which can be associated with the customer complaint.

- Care must be taken in the above procedures to avoid contact with moving or rotating components.

- Extreme caution must be taken while diagnosing an operating vehicle in the air to insure that the vehicle does not move.

Sophisticated automotive stethoscopes are available to assist in isolating a complaint. Some are based on the screwdriver technique and others are **electronic** with multiple clip-on microphones. The clips can be placed in different areas of the vehicle and monitored with earphones to determine the location of a condition.
Visual Inspection

A close look at the wheels and tires while a vehicle is on a lift can reveal many possible causes of complaints. Examples include:

- Wheel covers for fit, looseness and condition.
- Lug nuts and studs for proper size, torque, fit or condition. For example, a large locking lug nut can contribute to an imbalance condition that would not be corrected on an off car balancer.
- OEM wheels are important for proper fit and suspension geometry.
- Incorrect tire match (brand, size or inflation).
- Rotate the tire to look for obvious conditions such as damage, runout or lack of uniformity.
- Check the tread for wear that could indicate conditions that require correction. For example, alignment, balance, or worn suspension components.
- Listen for noises while rotating a wheel and tire. This will help identify loose components, foreign matter inside a tire or worn bearings.
- Look for evidence of tire filler or plugs that could contribute to an imbalance.
- Lodged ice, mud or other foreign material in the rim or suspension components.

The key to a successful visual inspection is to be familiar with the vehicle you are diagnosing and to pay particular attention to detail. Take the time to look closely at non complaint vehicles while performing other services. This will provide the experience that will be useful to quickly identify conditions that don’t normally exist on a vehicle.
This part of the pinpoint section is designed to be a reference that discusses diagnostic procedures relative to the common NVH conditions outlined in Section 1.

Conditions are grouped into three charts. They are the vibrating sources that are identified by the NVH Analyzer:

- Engine Symptoms Diagnostic Chart
- Driveline Symptoms Diagnostic Chart
- Wheel and Tire Symptoms Diagnostic Chart

Some conditions will appear in more than one chart. The use of the classification flow chart, road test and a knowledge of the theory relating to these conditions will insure that the proper pinpoint diagnostic procedures are being used.

Refer to the end of this section for the charts.

The pinpoint diagnosis determines the specific cause of the complaint and analyzes the possible solutions.

If a specific condition and solution is not identified at this point then the diagnostic steps need to be reviewed for areas that may require further investigation.

If the condition has not been resolved after carefully reviewing your diagnostic procedures and conclusions, then technical assistance should be consulted.

Be sure to have the details of the diagnosis ready when calling for help (Discussed in detail later).

Case study: Part IV

From the classification, road test and NVH Analyzer, it is established that the two symptoms are steering shimmy and body booming. They are caused by the driveline and wheels.

The NVH Analyzer indicates that the greatest amplitude is in the area of driveline. This would make a good starting point for pinpoint diagnosis.

Pinpoint diagnosis of the driveline would include checking the following:

- Balance
- Runout
- Angle
- U-joint inspection

This order was selected because the symptoms indicate balance as the most likely because the driveline spike was a first order vibration. (Section 1)

During the diagnosis for balance, it was found that the propeller shaft was out of balance.
Case study: Part IV
Continued

Balancing the shaft according to the procedures in Section 4, corrected one of the symptoms of the customer complaint.

A pinpoint diagnosis of the wheel and tire vibration includes checking the following:

- Balance
- Runout
- Condition

The symptom is a steering shimmy vibration and a distinct second and third order vibration was noticed. Therefore, wheel balance should be your first step. (See Section 1)

Section 4 and the 450 Suspension Systems course should be consulted for the proper balancing procedures.

Choose and Perform the Appropriate Repair

Once the pinpoint diagnosis has been performed revealing the problem, the technician has to make a critical decision regarding long term customer satisfaction: How to repair the vehicle effectively.

Depending on the condition or problem found, there are many resources available such as, the repair manual, TSBs, NCFs and EWDs. In addition, assistance is available from the FTS or the 800 hot line.

Unfortunately, in some cases, the industry has experienced a level of repair or a short cut procedure that is below standard and not in line with long term customer satisfaction. This usually occurs as a result of frustration due to a poor diagnostic procedure. Hopefully, the diagnostic procedures outlined in this course and the NVH Analyzer will minimize those frustrations.

Section 4 of this course deals with the common repair techniques used in NVH repair. Many of the other NVH repairs are standard service procedures detailed in the repair manuals.

Technical Assistance

Current vehicles are very complex and the amount of information required to successfully repair a vehicle the first time is enormous. Toyota recognizes this fact and has established systems to provide the technician with assistance. The areas for assistance are:

- TAS 800 hot line
- Field Technical Specialist (FTS)

During NVH diagnosis the possible conditions vary greatly and may or may not be easily serviceable by the technician. By using TAS, technicians can tap into resources which provide a data base of similar situations and successful solutions. Outside help can also provide some objective clarity to our diagnostic process and point out additional areas to examine.
Technical Assistance Continued

It is important to look at assistance as an additional tool and not a last resort or a sign of failure.

In order for assistance to be successful, however, there are key factors that must be in place prior to making your call:

- Good communication skills
- Organized diagnosis procedure
- Reliable data

Most assistance is done over the phone. The listener cannot verify the complaint or follow the diagnostic procedure on the vehicle and therefore must rely on what they are told. The use of standardized terms is critical. The symptoms and description must be clearly understood by both parties.

When both the technician and the engineer use the same diagnostic procedure, then the engineer can follow along in the same organized manner as the technician. The engineer can predict the steps and not get confused in trying to sort out a random diagnosis. At specific points in the discussion, the engineer will be looking for data that will support the decision process.

The engineer can now point out conditions to consider, in the diagnosis or the data, which will redirect the technician toward a successful solution.

He may confirm your conclusions and recommend further assistance to deal with a condition that is not serviceable by the technician.

Nobody likes to get “buried” in a job and customers do not like the service experience associated with the inability to satisfactorily resolve a complaint. As the service experience becomes unpleasant to the customer, they often become more difficult to satisfy.

The quicker the technician resolves the complaint, or identifies the need for outside help, the better the service experience for all involved.

It is important to note that jumping to assistance without making a concerted effort to follow the above procedures is also a waste of time. Without specific information, technical assistance cannot help, and will direct you to perform the procedures.

Summary

Technical assistance is an option for a technician when help is needed in diagnosing a serviceable complaint or in identifying when outside technical support is necessary.

The key is to have solid diagnostic data available and to use technical assistance as soon as it is necessary.

The object is to get the complaint resolved to ensure customer satisfaction and not wait until it is a last resort or too late.
Case study: Part V

The complaints on the 4Runner are easily diagnosed and resolved by the technician. Technical assistance should not be necessary in this case.

If the conditions found did not exist, yet there was still a verifiable complaint, then assistance should be consulted using the above criterion and the support documentation from the diagnosis.

Verify that the complaint has been satisfactorily resolved

The data collected while verifying and measuring the complaint will be useful as a basis for comparison of the effectiveness of the repair.

In many cases the vibration or sound will never completely go away. The objective may be to lower the amplitude to an acceptable level. The acceptable level may change for a customer as they become tuned into the complaint, especially if they are experiencing some frustration with the service experience. Simply showing the customer graphic printouts of the improvement may satisfy them.

The advantage of hard data is to objectively provide a comparison to show improvement or the acceptable levels of other similar vehicles.

Summary

When the complaint is successfully resolved and verified, then the vehicle is ready to be returned to the customer. You will have the confidence of knowing the diagnosis and repair was done right the first time and you will have the documentation to prove it.

If you cannot objectively verify that the complaint has been resolved, then the opportunity exists to go back through the process to find the condition, without the customer’s involvement.

Case study: Conclusion

A test drive with the NVH Analyzer verified that the complaint was resolved when a comparison is made with the data collected during the road test.

The next section of the course will deal with the common NVH repair techniques in greater depth.
Pinpoint Diagnosis

Symptom: Accelerator Pedal Vibration

Description:
Accelerator Pedal Vibrations occur at frequencies associated with engine speed.
They are usually of low amplitude and not in the direction of the pedal stroke.
They can usually be duplicated when the engine reaches a specific RPM regardless of vehicle speed.
If the vehicle is moving, the vibrations will go away when coasting in neutral.

Pinpoint Diagnosis includes inspection of the engine running condition at:
- the RPM recorded during the verification and classification sections
- idle quality both normal and under load (A/C, P/S, electrical load)
- fast idle quality both normal and under load
- cruise RPM

Pinpoint inspection also includes checking:
- the engine, transmission and accessories for contact with the body
- throttle lever and accelerator cables
  - check brackets, bushing and grommet
  - disconnect cable clamp and A/T throttle cable and see if the vibration changes. If the vibration disappears when the A/T throttle cable is disconnected then inspection of the transmission may be required
- accelerator pedal
  - play or looseness
  - return spring and free play
  - mass damper (if equipped)

Remarks: A complete TCCS diagnosis may be required to deal with engine driveability conditions that may contribute to engine related vibrations.
Shift lever vibrations are generated by engine torque fluctuations or imbalance of revolving or reciprocating engine components.

They occur at particular, high engine RPM and may be amplified by imbalance in the propeller shaft or shaft joint angle on a FR vehicle.

They may also be associated with a “buzz” sound.

**Symptom**  
**Shift Lever Vibrations**

**Description**

Shift lever vibrations are generated by engine torque fluctuations or imbalance of revolving or reciprocating engine components.

They occur at particular, high engine RPM and may be amplified by imbalance in the propeller shaft or shaft joint angle on a FR vehicle.

They may also be associated with a “buzz” sound.

**Pinpoint Diagnosis**

Inspection and repair of shift lever vibrations include the same engine condition inspections outlined in the accelerator cable vibration section, with the addition of the following:

- check the engine and transmission mounting for:
  - overall alignment
  - contact or looseness at mounting points
  - mount slit clearance
  - deterioration of rubber quality due to a leak

**Mounts**

Fig. 3-6
**Pinpoint Diagnosis**

**Continued**

- engine and transmission tightness including stiffener plates or brackets must be checked

**Stiffener Bracket**

Fig. 3-7

- shift lever
  - check for installation
  - wear of housing and retainer
  - action of the restriction pin

**Shift Lever**

Fig. 3-8

- shift control linkage and cable
  - check for bent linkage and excessive play
  - cables need to be checked for proper flex, contact with other components and excessive play
Transmission Condition
Fig. 3-10

Remarks

The two piece oil pans on later model vehicles have been designed to improve NVH characteristics. Stiffener plates are not used on these vehicles.
Pinpoint Diagnosis

Symptom: Engine Noise

Description: Engine noise is engine speed related and may require a change in load.

Pinpoint Diagnosis

Engine noise is most commonly diagnosed by searching for the source visually or with a stethoscope.

Other techniques such as, removing a plug wire and grounding it or disconnecting an injector, can help identify the location of an internal engine noise. By changing the firing load in a cylinder, noises from a piston, piston pin or rod bearing condition may change, identifying a cylinder causing the complaint.

Vehicles with multiple belts can be diagnosed by removing the belts one at a time until the condition changes. Accessories associated with the belt and the condition of the belt should be checked. Components include:

- fan
- fan shroud
- alternator
- water pump
- A/C compressor
- idler pulley
- P/S pump

Engine Accessories

Perform diagnosis quickly when belts are removed so that problems such as overheating will not occur.
The air intake system can also be a source of both noise and vibrations. This system is designed to deliver filtered, fresh air to the engine with minimal noise. Many systems incorporate resonators to accomplish noise reduction.

A technician can inspect the air intake system:
- for the proper components properly connected
- to see if the complaint can be modified by pushing on or disconnecting components or hoses
- for proper mounting and mount condition
- for foreign material that can make noise or cause an obstruction

The exhaust system is discussed in many areas of this course as a possible transmitter of engine vibration and noise through body contact. You should also consider the possibility of exhaust restriction as a potential noise source. Vehicles with this condition would also exhibit power loss under load. A vacuum gauge is very helpful in pinpointing a restricted exhaust condition.
Symptom: Clutch Judder

Description:

Clutch judder can be reproduced during partial clutch engagement when the vehicle encounters rolling resistance, for example, climbing a grade. This condition can be simulated by lightly applying the brake during clutch engagement.

Pinpoint Diagnosis:

Engine running condition needs to be considered as well as the condition of the motor mounts when troubleshooting engine noise.

Suspension bushings need to be inspected by prying them apart and checking the slits provided to minimize vibration and noise. The suspension system can be a transmission path for normal vibration during clutch engagement.
Pinpoint Diagnosis
Continued

Rubber Insulator
Fig. 3-17

The pedal height, free play and movement need to be checked while operating the pedal. Repair manual procedures contain the specifications should an adjustment be required.

Clutch Pedal Free Play
Fig. 3-18

A driveshaft can cause a clutch judder condition. It should be checked for smooth operation without excessive free play.

Driveshaft
Fig. 3-19
When external inspections do not produce the condition then inspection of the clutch assembly is necessary. This includes the following:

- Toyota clutch components are specifically designed to meet the torsional characteristics required for torque fluctuation of the engine. These components are recommended to ensure the best operation of the clutch.
- the clutch release lever needs to be checked for mounting, alignment and wear.
- the release bearing should be checked for proper alignment and smooth movement. Retaining clips should also be checked.
- the pressure plate assembly and diaphragm spring must be inspected for:
  - wear
  - spring tension and alignment
  - evidence of heat that would effect the temper and tension of the spring
  - evidence of discoloration or hard spots on the pressure plate and flywheel
  - scores, grooves or runout in the pressure plate or flywheel
  - warpage of the pressure plate mounting assembly due to uneven torque or loose mounting bolts
  - clutch disc surface condition, rivets, torsion springs, and spline must be looked at closely
- close inspection of the transmission input shaft spline and pilot bearing also reveal the cause of the complaint
Symptom  
Take-Off Vibration

Description

Take-off vibration occurs when the vehicle transitions from a stop to initial acceleration. It can be noticed in the dash, steering wheel (vertical movement) and floor on FR vehicles.

This type of vibration occurs at low frequency (15 to 30 Hz) for short periods of time and may be extended by idling slowly up a hill.

Pinpoint Diagnosis

Torque fluctuations are transmitted to the body through the following areas:

- The exhaust system needs to be checked:
  - when it is both cold and hot because it will expand and contract with temperature
  - for overall exhaust system tension by looking at the load on each rubber mount. Loosening the entire system to relax the tension and retightening it is effective in resolving many complaints
  - for damage
  - for alignment
  - for OEM components
  - for the condition of rubber mounts for hardening, cracks and elasticity
  - for rubber stoppers, clamps and the body for evidence of contact
Pinpoint Diagnosis
Continued

Engine Mounting
Fig. 3-24

- Engine mounts can be inspected as in other engine related NVH diagnosis. Engine torque type complaints relating to mounts or contact can be duplicated by rocking the power train. This is done by increasing the RPM with the vehicle in gear, wheels blocked and the brakes applied. Both drive and reverse should be used.

- The drive shafts must rotate smoothly without excessive play. Both conditions are sensitive to torque fluctuations.

- Take-off vibrations that are felt in the floor may be produced by the propeller shaft and transmitted through the center carrier. An inspection of the propeller shaft includes checks for:
  - play at the extension housing and yoke
  - missing weight (look for a trace of a spot weld)
  - joint phase
  - smoothness and runout (rotate shaft manually)
  - center bearing alignment both vertically and horizontally

Remarks

CAUTION

Do not perform the engine torque test at high RPM or for extended periods due to overheating of the engine, torque converter or transmission.

See Section 4 for details on propeller shaft inspection and repair.
### Symptom: Crank Vibration

**Description:** Crank vibration occurs at a low frequency (5 - 15 Hz) during engine cranking.

**Pinpoint Diagnosis:** Engine related conditions that impact torque fluctuation during cranking include:

- uneven compression between cylinders (diagnose with a power balance and/or compression test)
- ignition timing and excessive engine temperature (The complaint verification section is very helpful in this area because the complaint will not occur every time the engine is cranked.)
- hydraulic lock in a cylinder due to a leaking injector or head gasket
- worn starter bushings (diagnose with a starter current draw test)

Transmission of normal cranking vibrations through the exhaust system and engine mounts are diagnosed the same as in the previous engine conditions.

### Symptom: Idle Vibration

**Description:** (10 - 50 Hz)

**Pinpoint Diagnosis:** Idle vibrations require the same diagnosis procedures as cranking vibrations with the addition of an engine idle quality inspection.

They may be more noticeable when the engine is under load, for example, when in gear or with the A/C on. Vehicles with transverse-mount engines are more sensitive to idle vibrations that are transmitted through the exhaust system.

If it is found that an engine performance condition is the cause of the symptoms then a thorough TCCS diagnosis is recommended.
Symptom | Body Booming Noise
---|---
Description | Body booming noise is a symptom that can be caused by engine, driveline and tire/wheel conditions.

NOTE
Be sure to check the details in all three source areas when diagnosing a body booming symptom.

Pinpoint Diagnosis
Establishing whether a symptom is engine speed related or vehicle speed related is the first step in determining which area to focus the pinpoint tests. Engine related symptoms can be heard while increasing the engine RPM, therefore, the engine can be eliminated as the cause if the noise is heard while coasting in neutral.

The exterior of the body should be checked for conditions that may resonate with normal vibrations. A thorough visual inspection is important to find conditions such as fit, looseness or damage of body components. An overall look at the vehicle ride height will help you identify conditions such as uneven tire inflation.

Inspection for engine noise should be performed through all operating engine speeds including the RPM that produces the most noise. All engine driven accessories should be operated to see if they contribute to the condition.

A technician should look at the belts, component fit, rattle or contact and any foreign material lodged between components. Engine mounts should be checked during this inspection as mentioned before.

While duplicating the noise, see if it changes while modifying the intake air duct system, such as disconnecting or pushing on it.

The exhaust system is also an area that will cause a body booming noise which is engine related. The system should be checked for damage, mounting, contact with the body and clamp condition. As stated before, the system should be checked to determine that it is properly designed for the vehicle.

An exhaust system changes shape with temperature and should be checked in all temperature ranges. Modifying the system by removing hangers or placing a jack under it to keep it stationary will also help to isolate the exhaust system as the cause.
Body beating noise requires two vibrations as discussed in Section 1.

It is being addressed in the engine area because the vibrations generated by the engine can be one of the two vibrations involved.

Engine vibrations contributing to body beating include imbalance and torque fluctuation. Imbalance is a first order vibration, while torque fluctuation is a second order vibration on four cylinder engines and third order on six cylinder engines.

A vibration from the engine area combined with one from the driveline or wheel will create the body beating symptom. Resolving this type of complaint can be done by eliminating either one of the vibrations or reducing both of them to a minimal level.

Duplicating a beating noise requires a slow change in engine RPM while waiting for the symptom to occur. A beating noise is most noticeable at a frequency between 2 and 6 Hz therefore the technician needs to hold a constant speed long enough for the symptom to appear.

Body beating is a cyclical sound which will occur at a particular RPM. This RPM should be identified during verification of the complaint.

Both engine speed and vehicle speed are required to create this symptom, therefore the vehicle speed should also be identified during verification for diagnosis of the second vibration.

The specific pinpoint tests for the engine vibration are the same as those for body booming noise. In addition, the engine and transmission tightening and the stiffener bracket should also be inspected.
Transmission gear whine and Differential gear whine are very similar sounds that are not likely to be noticed on the NVH Analyzer. The frequency range is between 400 and 3k Hz for transmission gear whine and 400 to 1500 Hz for differential gear whine which are above the 500 Hz range of the NVH Analyzer.

To pinpoint the source of gear whine, first determine which symptom exists. The road test will be the most useful technique for this step.

- Operate the vehicle at the speed the whine is most noticeable.
- Then change the speed of the vehicle to see if the noise is speed related.
- Next change gears to determine if the noise changes with different gear selections.
- Note the level of the noise when the gear ratio is 1:1. At this ratio the power flow is direct through the transmission and the load on the gears is the minimal.

Differential gear whine is vehicle speed related and will not change with different gear selections.

The transmission path is an important area of pinpoint diagnosis for both transmission and differential gear whine. Inspection of components that could transmit noise to the passenger compartment will often resolve the complaint.

Inspection of body sound insulators is also important in gear noise diagnosis. The technician should look for the following:

- gaps in body panels
- damage to grommets, body molding, boots and seals
- condition of sound absorbing materials such as asphalt sheets, silencer pads and floor carpets.
If it is determined that the noise is coming from the transmission or differential, careful inspection of the gears as well as the bearings is important.

Gear whine and bearing noise are very similar, depending on the condition of the bearings, and difficult to isolate in a test drive. Bearing condition could also have an effect on gear mesh and condition.

A thorough understanding of the transmission power flow, will help anticipate the gears and bearings causing the problem during the test drive.

The repair manual is an important resource to consult when diagnosing and repairing internal transmission and differential noises. Procedures and specifications are available to insure the component is repaired properly the first time.
Body booming noise is discussed in the engine pinpoint diagnosis chart specific to causes that are engine related. In this area, pinpoint diagnosis of body booming noise conditions related to driveline are discussed.

**Pinpoint Diagnosis**

A visual inspection includes checking for proper U-joint phase. Fig. 3-29 shows the proper position of the U-joints on the different shafts.

On a 3-joint propeller shaft the center bearing position must be checked for vertical and horizontal alignment.

The shafts should be rotated, checking for free movement, smoothness, unusual noises or looseness. Visual inspection for alignment, damage or contact with other components such as cables or the exhaust may pinpoint the cause of the complaint.

Specific details on the following are covered in Section 4 of this course:

- driveline balancing
- runout measurement and correction
- angle adjustment and repair
The NVH portion of the Diagnostic Tester is very helpful in isolating the source of the vibration including differentiating between balance, runout and angle conditions.

- First order (primary component) driveline vibration is associated with balance or runout conditions.
- Second order (secondary component) driveline vibration is associated with U-joint condition such as angle, tightness or looseness.

As discussed in the engine body beating noise section, it requires two vibrations to cause a complaint. The driveline is one of the possibilities to consider, especially if the NVH Analyzer indicates a strong vibration in the driveline area.

Pinpoint diagnosis of a body beating noise is the same as the pinpoint diagnosis of the driveline for body booming noise.
Wheel Pinpoint Diagnosis

**Symptom**  
Body Shake, Steering Flutter, and Steering Shimmy complaints all involve pinpoint diagnosis of the same components. The condition of the component is what determines which of the symptoms occur.

The wheels and tires are a good place to start especially if the NVH Analyzer identifies this area as the generating force of the vibration.

**Pinpoint Diagnosis**

- Checking all four tires for the same manufacture, size, and specifications. Proper tire pressure is also an important item to confirm.
- Looking for damage, deformation and wear. The technician should also rotate the tire and wheel assembly, looking at both the side wall and tread, to reveal obvious conditions caused by internal tire damage, flat spots or runout.
- Feeling the tread for unusual wear patterns that may be abnormal. This will direct the technician to conditions that need to be corrected.

- The tire and wheel needs to be checked for proper bead seating all the way around, on both sides.

- Hub to wheel centering is important to insure that the clearance is even and within the target value of 0.1 mm (0.004 in.) max. If the clearance is out of spec. then the wheel can be rotated to minimize the difference. If the clearance is still out of spec. then check the hub for runout to determine if the condition is in the wheel or hub.
There are two types of runout to check on the tires, wheels and hubs:

- radial
- lateral

Radial runout is the change in the radius as it rotates. It is measured with a dial indicator that is mounted in a stationary position, parallel with the rotating plane. Check radial runout through one complete 360° rotation of the tire and wheel assembly.

Lateral runout is the side to side movement.

A dial indicator is used to measure the runout as the tire and wheel assembly is rotated 360°.

The balance of rotating components must be checked including the tire, wheel, hub, drum or rotor.

- Tires and wheels are commonly balanced off the car which takes into consideration irregularities of the tires and wheels
- Dynamic balancing (wheel and tire in motion) is recommended for accuracy as compared to static or bubble balancing
- On car balancing or finish balancing not only includes tires and wheels but also checks everything that rotates (ie: hub, rotor/drum and bearings).
While performing an inspection, the technician should keep in mind components in other areas that will resonate at wheel speed. This includes many components in the steering and suspension systems.

Steering system component checks include:
- ball joint play
- leakage
- steering linkage play or damage
- steering damper condition
- condition of the rubber bushings

Suspension system components checks include:
- condition of suspension arms and bushings
- condition of the springs
- wheel bearing adjustment
- shock absorber inspection for leaks, bushing condition and proper operation

Tire wear may cause a vibration but may be the result of another condition such as incorrect wheel alignment or worn components. The technician needs to do a thorough inspection to be sure the original cause of the condition is repaired.

Details on measuring and correcting runout are discussed in Section 4.

Details on balancing are also included in Section 4.
Riding Comfort, Harshness, Road Noise and Tire Pattern Noise are all different symptoms with different characteristics as discussed in Section 1. The generating forces in these conditions are caused by contact with the road which we have no control or cannot change. What we have control over is the transmission path of the impact through the vehicle.

The transmission path and the components to inspect are the same for all four of the above conditions, therefore the pinpoint diagnosis will cover the same systems and components.

The components in these areas to check are also similar to the inspections discussed in previous pinpoint diagnosis of tire and wheel vibrations:

- tire and wheel
- suspension
- body sound insulators

In all pinpoint diagnosis it is important to look for changes from the manufacturer’s original condition.

For example:

Low aspect ratio/profile tires are popular for appearance to some customers. These tires do not have the same ride characteristics as the original profile tire. The customer will feel a greater impact from road irregularities.
Symptom: Brake Vibration

Description: Brake vibration occurs only when the brakes are applied. As a result the technician can go directly to pinpoint diagnosis.

Pinpoint diagnosis of this condition includes inspection of the:

- pedal for lateral play
- rotor for surface condition such as rust, grooves, glazing, hard spots, evidence of overheating and evidence of poor surface condition
- rotor runout and parallelism (target value 0.1 mm (0.004 in.) or less)
- drum to shoe contact surface condition for rust, grooves, glazing, hard spots, evidence of overheating and evidence of poor surface condition.
- Wheel bearing adjustment and condition needs to be checked
- Shoes and Pads must be checked for glazing, cracks, uneven wear and proper installation. OEM is recommended to insure the proper function and friction characteristics.
- Disc brake hardware should be checked for looseness, wear, dirt, leaks and operation.
- Drum brake hardware checks include proper assembly, spring tension, damage, leaks, wear and operation.
- The surface of the wheel that mounts to the hub should be flat with no cracks. target value - 0.1 mm (0.004 in.) or less. It is important to check hub and axle runout before making corrections for rotor, drum runout or wheel and tire runout. A bent axle will cause all of the components to indicate a runout condition if checked while on the vehicle.
Symptom  
Brake Squeak

Description  
Brake squeak is associated with the contact of the pads/shoes to the rotors/drums.

Inspection and repair involves inspection of:
- The surface of the linings and pads for wear, hardness, and shine.
- Pad/shoe contact, by placing them against the rotor/drum surface and noting even contact.

• Brake component tightness including the backing plate, hub and rotor, caliper mounting and slide pins.
Pinpoint Diagnosis
Continued

- Anti-squeal shims and pad support plates for assembly accuracy and damage.

**Brake Pad Anti-squeal Shims**
Fig. 3-42

**Symptom**  Body Booming Noise, Body Beating Noise

**Description**  Body booming noise and Body beating noise are symptoms that can originate from wheels and tires. Body booming noise from tire uniformity and a tire/wheel vibration can also be one of the two vibrations required for body beating noises.

**Pinpoint Diagnosis**  To pinpoint the cause of these conditions use the same procedures as with other wheel and tire vibration diagnosis.

**Remarks**  More than one tire out of balance at different pressures can be the cause of beating due to the slightly different diameters of the tires.
Lesson Objectives

1. Identify the common repairs specific to NVH.

2. Demonstrate the ability to use the NVH Repair Techniques Chart to select a repair technique that will quickly resolve the complaint the first time.

3. Demonstrate the ability to:
   - Measure propeller shaft runout
   - Measure and correct driveline angle
   - Measure tire runout
   - Phase match a tire and rim
   - Use the interior & wind noise programs
Introduction

The repair section of the course deals with the techniques that are specific to NVH repairs and require additional information. Many of the solutions covered in Section 3 are obvious, after an inspection reveals the cause of the condition. The repair manual should be consulted for the specific procedures relating to these repairs.

For example:

If a pinpoint diagnosis requires an inspection of a motor mount and it is found to be worn, then replacement is the obvious repair.

The technician should next determine why the mount became defective, such as an oil leak causing the rubber to deteriorate. In this case the oil leak would be repaired to insure long term customer satisfaction.

In both of these cases the repair manual would be the best resource for the appropriate repair procedures.

The following is the list of NVH repair techniques that are covered in this section either in the Repair Techniques Chart, the worksheets or both:

Driveline
- Propeller shaft balancing
- Runout
- Angle

Wheel and tire
- Balance
- Runout lateral/radial

Squeaks, Rattles and Wind Noise
- Diagnosis
- Repair
## Repair Techniques Chart

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driveline Propeller Shaft Imbalance</td>
<td>Propeller shaft imbalance is one of the major causes of a <strong>first order driveline vibration</strong>.</td>
</tr>
<tr>
<td>Driveline Runout</td>
<td>Runout can also cause a <strong>first order driveline vibration</strong>.</td>
</tr>
<tr>
<td></td>
<td>Runout conditions can be in the shaft or in the mounting flanges/splines on the end of the shaft. It is important that both are checked before servicing the shaft.</td>
</tr>
</tbody>
</table>
REPAIR TECHNIQUE

When servicing a driveline condition be sure to perform a thorough visual inspection for:
- component condition or damage
- excessive undercoating or other foreign material
- evidence of a collision which would explain component alignment conditions

For example:
   If a U-joint is found to be worn and loose then it must be repaired before checking the runout of the shaft.

Propeller shaft balancing is a technique that requires the use of specialized equipment to determine the location and the amount of the imbalance.

Equipped with the details from the NVH diagnostic procedures the technician can call the FTS (Field Technical Specialist) or the FPE (Field Product Engineer) with the balancing equipment for assistance.

Once the location and the amount of imbalance has been determined, there are three options:
- weighted bolts can be used to offset the imbalance condition
- the shaft can be sent out to a specialty shop for service
- the shaft can be replaced

A dial indicator is used to measure the amount of runout. Proper mounting is important for accurate readings. It can be mounted to a solid part of the vehicle or on a stand from the floor. The dial indicator or mount should not move while taking readings and the indicator must be perpendicular to the surface being measured.

The surface of the shaft must be smooth and free of irregularities such as undercoating or corrosion.

Each shaft should be measured at several locations which will help determine the actual cause of the runout.

For example:
   If the runout is greater in the middle than on either end then the shaft is likely the problem and should be measured on the bench in “V” blocks.

   If the runout is greater on one end then in the other two locations the flange should be checked for runout before servicing the shaft.

   If runout is determined to be associated with the mounting surface at the flanges, rotate the shaft 180° which may bring the runout within specification. If not measure the runout of the flanges to determine the problem.

REMARKS

Always refer to the repair manual for the proper procedures, specifications and cautions specific to the vehicle and components being serviced.

CAUTION: During any propeller shaft service off the vehicle, do not use excessive force when clamping a shaft in a vise. Damage could result.

When servicing components in a vehicle that require disconnecting part of a propeller or a driveshaft, do not let the shaft hang freely in the vehicle. Damage may occur to U-joints, centering pins or CV joints causing new complaints.

After the repair, be sure to perform the verification procedures while the balancing equipment is available to insure customer satisfaction.

Do not remove the flange with a hammer as damage could result.

Specifications for runout and other driveline service procedures are available in the repair manual.
## Repair Techniques Chart (continued)

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
</table>
| Driveline Angle          | Driveline angle conditions or working angle may cause a second order vibration. Any vibration associated with a condition in a propeller shaft joint will be a second order vibration because the vibration occurs twice per revolution. A joint accelerates and decelerates twice per revolution. As the working angle increases the acceleration and deceleration rate increases causing the vibration. Correcting a vibration caused by an improper working angle involves a series of measurements on two planes to determine the angles that exist in a vehicle. The two planes are:  
• horizontal  
• vertical  

A constant rotation of the output shaft of the transmission changed to two accelerations and decelerations at the U-joint as the angle changes. The greater the angle the greater the change in speeds. The second joint is designed to counteract this change in speed and provide a smooth constant rotation to the differential. In order to do this the working angle must be as close to the same as possible. |
| Wheel and Tire Imbalance | Wheel and tire imbalance is one of the most common causes of first order wheel vibrations.  

There are three styles of balancing:  
• static (bubble balancing) not recommended  
• dynamic balancing off car  
• dynamic balancing on car  

Static balancing is a technique that was common in the past but does not provide the quality balance that a dynamic balancer is able to achieve. An on-car balancer or finish balancer will take into consideration all components that rotate with the wheel such as the hub, rotor/drum, and axle. |
<table>
<thead>
<tr>
<th>REPAIR TECHNIQUE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Horizontal</strong></td>
<td>A thorough visual inspection is very important to uncover clues for changes in the angles. If a condition is discovered that caused the angle change, such as collision damage, then it must be corrected before proceeding with the measurements and adjustments.</td>
</tr>
<tr>
<td>Horizontal measurements involve plumb bobs and tape to determine the centerline of the engine and transmission. The center line needs to be checked for position in the vehicle to determine if a condition exists such as a worn mount or a bent frame. For frame measurement, a body service technician with proper measuring equipment should be consulted. When checking the differential, the center line of the axle must be perpendicular with the center line of the driveline. Once all the measurements have been taken then the technician can determine where a deviation exists from the center line and make the appropriate adjustments to correct the condition. For example: A two piece shaft with a center carrier bearing could be misaligned at the center point of the carrier bearing. Adjusting the carrier will bring the shaft into alignment and reduce the working angle of the joints. Experience with non-customer complaint vehicles is very helpful in determining angles that are acceptable. Comparing these angles with those of a complaint vehicle will help determine which angle should be adjusted, how far and in what direction.</td>
<td>The joint angle should not exceed 5°. Front and rear joint angles should be within 1/2° of each other. Vehicles that have been lowered or raised will have vibration as a result of different working angles unless considerable changes have been made to compensate for the change in height.</td>
</tr>
<tr>
<td><strong>Vertical</strong></td>
<td>If a customer identifies a vibration when a vehicle is fully loaded, then the customer should duplicate the load prior to taking measurements. When making measurements the vehicle has to be raised maintaining the same suspension as in the normal operating condition. This will ensure that the measurements reflect the actual working angles during normal operation.</td>
</tr>
<tr>
<td>Vertical measurements require an SST 09370-50010-10 which measures the angle of a component in reference to a horizontal line. The horizontal line is established with a plumb bob or a bubble level depending on the style of tool used. The SST measures the angle of the engine/transmission, propeller shafts and the differential and compares them to each other. The object is to cancel out the effect of the working angles of the joints. If the working angle is found to be excessive then the technician must determine the best location for adjustment to minimize the difference in the angles.</td>
<td>This course is an advanced level course and not intended to train the technician in tire balancing. The remarks in this section are intended to help the technician pay attention to the details that are required to ensure customer satisfaction.</td>
</tr>
<tr>
<td><strong>Before</strong></td>
<td>There are many styles of wheels and wheel weights available especially when considering the aftermarket. It is important that the proper style of weight be used on a wheel to ensure that they will stay on and not come off causing a repeat complaint.</td>
</tr>
<tr>
<td>balancing a tire and wheel the following should be checked:</td>
<td></td>
</tr>
<tr>
<td>• damage or deformed tires and wheels</td>
<td></td>
</tr>
<tr>
<td>• foreign matter on the rim especially on the inside of the rim</td>
<td></td>
</tr>
<tr>
<td>• all the existing weights are removed</td>
<td></td>
</tr>
<tr>
<td>• foreign material inside the tire like water, stop leak or loose rubber, especially if the balance position and weight amount changes on a re-check</td>
<td></td>
</tr>
<tr>
<td>• the tread for plugs that may cause an imbalance or locate a broken cord</td>
<td></td>
</tr>
<tr>
<td>• heavy or large custom and locking lug nuts</td>
<td></td>
</tr>
<tr>
<td>While balancing a tire note the amount of weight required to balance the tire. An excessive amount will indicate a tire that should be replaced because the vibrations will never be completely resolved.</td>
<td></td>
</tr>
</tbody>
</table>
**Repair Techniques Chart** (continued)

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel and Tire Runout</td>
<td>Wheel and tire runout (lateral/radial) will also generate a <strong>first order vibration</strong> and can often be diagnosed with a good visual inspection if the runout is great enough. This is usually the case when there is tire damage. If the tire is damaged then replacement is the best repair.</td>
</tr>
</tbody>
</table>
| Squeaks, Rattles and Wind Noise | Squeaks, Rattles and Wind Noise discussed in this section are those that are **not** diagnosed with the NVH Analyzer because their frequency is **above 500 Hz**. Noises below 500 Hz are discussed in Section 3.  

The most difficult task in servicing interior and wind noise is **locating** the source. Some noises are very illusive and seem to be coming from different areas of the vehicle depending on the customers location in the vehicle. This is caused by different transmission paths from the same source. |
For runout conditions that are not obvious, a dial indicator is used to measure both radial and lateral runout. Mounting the dial indicator on a stand provides good results. A wheel adaptor for the dial indicator allows easy movement of the indicator over the rubber surface.

A smooth surface will provide the most accurate readings. Lateral runout measurements are taken from the side wall of the tire where a smooth surface can be found. Radial runout is measured on the tread. Tape can be wrapped around the tread to provide a smooth surface.

Radial and lateral runout can also be measured on a rim using a stand and the wheel adaptor for the dial indicator. See fig. 3-34.

Some radial runout conditions can be resolved by phase matching the tire and rim. The use of a radar chart can help match the runout of the rim 180° from the runout of the tire which will minimize the total runout and the associated vibration.

The tire and rim should be marked in 12 locations and the runout recorded on the radar chart for the tire and rim corresponding to those locations. The chart will have two sets of marks one relating to the tire and one to the rim which can be connected showing the runout of each from center and their relationship to each other.

The spot of the greatest runout from center should be marked on the tire and rim. Dismount the tire and rotate the tire so that the marks are 180° apart. Remount the tire and measure the radial runout with the dial indicator to determine if the total runout has been reduced.

An axle could also be the cause of excessive lateral and radial runout.

For example:
A vehicle could have slid into a curb with enough force to bend the axle or spindle. A damaged wheel and tire is easily replaced by the customer without noticing the damage to the axle. A visual inspection may spot a tire and wheel that is newer than the others indicating the need for closer inspection for runout.

Radial runout should be measured on the wheel lugs as well as the axle flange.

Lateral runout is measured on the face of the flange.

The mating surfaces of the wheel and flange should be checked to ensure a flush fit. Any contamination could cause a lateral runout condition.

Toyotahas published two programs to assist the technician in diagnosing and repairing interior and wind noise.
- Interior Noise P/N 00501-42857-R92
- Wind Noise P/N 00401-42979

These programs outline diagnostic procedures and illustrate techniques to isolate and locate the noises. They also include service tips specific to models for known sources of noise and the appropriate repair. These programs are updated periodically providing current information on the latest models.
WORKSHEET #5
Propeller Shaft Runout

Repair Technique: Propeller Shaft Runout Measurement

First order driveline vibrations are commonly caused by propeller shaft imbalance or runout. Second order is commonly associated with U-joint conditions.

This worksheet will provide practice using the skills to measure the runout of the propeller shaft and companion flanges with a dial indicator. You will also determine the best plan to resolve the condition, i.e. component replacement or phase matching the companion flanges.

**Propeller Shaft Runout Measurement**

1. Use a dial indicator to measure the runout of a propeller shaft in the vehicle and record your readings on the chart. Mark the rear point on the shaft of greatest runout.

2. Remove the propeller shaft, while referring to the repair manual procedures, and measure vertical and horizontal runout of the differential companion flange.

3. Determine if phase matching the shaft and the flange will improve the total runout.

4. Measure the runout of the propeller shaft, in the same three locations, using “V” blocks on the bench and compare your reading to those taken while in the vehicle.

5. Compare your readings to the specifications to determine serviceability.
### Questions

1. What **two** important factors must be considered when setting up and measuring a shaft with a dial indicator?

2. What should be checked prior to measuring a shaft for runout or balance?

3. Why is it recommended to check each shaft in **three locations**?

4. What are the **specifications** for propeller shaft and flange runout? List **two** locations for the specifications?

---

<table>
<thead>
<tr>
<th>LOCATION COMPONENT</th>
<th>FRONT</th>
<th>CENTER</th>
<th>REAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERMEDIATE SHAFT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PROPELLER SHAFT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In &quot;V&quot; BLOCKS</td>
<td>VERTICAL</td>
<td>HORIZONTAL</td>
<td></td>
</tr>
<tr>
<td>DIFFERENTIAL FLANGE</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Questions (continued)

5. What is your plan of action if you find conflicting specification?

6. Is there a difference in the readings taken in or out of the vehicle? If so, what is your conclusion?

7. List two considerations when servicing a propeller shaft.

8. What areas should be checked for runout in addition to the ones measured in the worksheet?

9. Which runout measurement location on the propeller shaft is most likely to indicate a possible companion flange runout condition? Explain.

10. What is the advantage of marking the high point on the rear of the propeller shaft?

11. If the high point is near the original high point after phase matching what is your conclusion?
A propeller shaft angle condition is one of the causes of a **second order** driveline vibration. Angle measurement and adjustment involves the use of the **SST 09370-50010-10** and **shims**.

This worksheet is designed to provide **practice** in propeller shaft measurement and adjustment using the resources mentioned above.

**Instructions**

**Vertical Joint Angles**

Fig. 4-2
Measurement

1. Raise the vehicle maintaining the same suspension system load and position as when the condition exists.

2. Measure the joint angle of the engine and the intermediate shaft (A) using surfaces that are parallel to the engine crankshaft on the engine and the shaft surface for the intermediate shaft.
   - crankshaft pulley
   - oil pan mounting surface
   - bell housing mounting surface

3. Set the gauge to zero while on the engine and read the change on the gauge while on the intermediate shaft. The change is the joint angle (A). Record the results on the chart.

4. Measure the intermediate shaft and the propeller shaft angle (B) making sure the SST is directly against the shafts.

5. Set the gauge to zero while on the intermediate shaft and read the change on the gauge while on the propeller shaft. The change is the joint angle (B). Record the results on the chart.

6. Measure the propeller shaft and differential angle (C) using the parallel or perpendicular surfaces to the drive pinion.
   - companion flange surface
   - differential cover mounting surface
   - differential carrier mounting surface

7. Set the gauge to zero while on the propeller shaft and read the change on the gauge while on the differential. The change is the joint angle (C). Record the results on the chart.

8. Compare your results to the specifications and determine what adjustments that must be made.

<table>
<thead>
<tr>
<th>COMPONENTS</th>
<th>JOINT ANGLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGINE/INTERMEDIATE SHAFT</td>
<td>(A)</td>
</tr>
<tr>
<td>INTERMEDIATE/PROPELLER SHAFTS</td>
<td>(B)</td>
</tr>
<tr>
<td>PROPELLER SHAFT/DIFFERENTIAL</td>
<td>(C)</td>
</tr>
</tbody>
</table>
Questions

1. What lift points did you choose to maintain the suspension height while raising the vehicle?

2. What are the increments between the degree marks on the scale?

3. How do you know if the angle is positive or negative?

4. Does it make a difference which component you measure first when using the angle gauge?

5. What are the specifications that are acceptable?

6. How do your results compare to the specifications?
Correction

1. **Correction** is done by adjusting the engine, center support bearing or differential. The object is to:
   - equalize the engine and differential angle
   - reduce the joint noise

   **NOTE** Some vehicles require “0” angle installations while others allow for the engine and differential centerline to be parallel where the joint angle of the engine and the differential are equal. Consult your repair manual for the proper correction procedure.

2. From the **measurements** determine what **adjustments** are necessary to make the engine and differential joint angles **equal** i.e.
   - front of the engine
   - rear of the transmission
   - which differential mount

3. From the **measurements** determine the **impact** of raising or lowering the center support bearing.

4. Using the shims provided raise or lower the component necessary to correct the condition.

5. Perform the **verification procedures** discussed in section 3 to ensure the condition has been **corrected**.

<table>
<thead>
<tr>
<th>THICKNESS</th>
<th>PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5 mm (0.177 in.)</td>
<td>90201-10008</td>
</tr>
<tr>
<td>6.5 mm (0.256 in.)</td>
<td>90201-10017</td>
</tr>
<tr>
<td>9.0 mm (0.354 in.)</td>
<td>90201-10033</td>
</tr>
<tr>
<td>11.0 mm (0.433 in.)</td>
<td>90201-10034</td>
</tr>
<tr>
<td>13.5 mm (0.532 in.)</td>
<td>90201-10035</td>
</tr>
</tbody>
</table>
Questions

1. What adjustments should be made to the following?
   - Engine mounts: Up or Down
   - Rear transmission mounts: Up or Down
   - Center carrier: Up or Down
   - Differential: Up or Down

2. What is the relationship between the thickness of the shim and the change in the joint angle? i.e. thousandths vs. degrees.

3. What determines this relationship between shim thickness and angle in question #2?

4. Did the condition improve after the adjustment?
   - differential cover mounting surface
   - differential carrier mounting surface
Description: **Horizontal Joint Angles**

Horizontal joint angles can have the same impact on vibration as the vertical joint angles but are more difficult to measure. Due to the acceleration and deceleration of a joint as it rotates it is important to ensure that the working angles cancel these changes in speed and provide a smooth output and no vibration.

The following sheet is designed to provide instruction and practice in measuring and correcting these horizontal joint angles.

**Instruction**

*Horizontal Propeller Shaft angle*

*Fig. 4-3*
Measurement Instructions

Engine

1. Raise the vehicle maintaining the same suspension system load and position as when the condition exists.

2. Drop a plumb line from the crank pulley and place a strip of tape under the plumb points. Mark the plumb points A and B on the tape.

3. Determine the mid-point (1) between points A and B.

4. Drop a plumb line from the transmission extension housing and place a strip of tape under the plumb points. Mark the plumb points C and D on the tape.

5. Determine the mid-point (2) between points C and D.

Intermediate and Propeller Shafts

6. Use the same techniques outlined above to determine the mid-points of the ends of each shaft:
   - mid-point (3) of E and F
   - mid-point (4) of G and H
   - mid-point (5) of I and J
   - mid-point (6) of K and L

Differential

7. The same techniques are used to measure the companion flange and both axle housings:
   - mid-point (7) of M and N
   - mid-point (8) of P and Q
   - mid-point (9) of R and S

8. (10) is the perpendicular intersection of the center line formed with (8) - (9) and the pinion drive through (7).

9. Connect all center lines with thread.

10. Place a protractor on the thread at joint angle (A), (B) and (C) to measure the angles. Record your readings on the chart.
### COMPONENTS

<table>
<thead>
<tr>
<th>COMPONENTS</th>
<th>JOINT ANGLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGINE/INTERMEDIATE SHAFT</td>
<td>(A)</td>
</tr>
<tr>
<td>INTERMEDIATE/PROPELLER SHAFTS</td>
<td>(B)</td>
</tr>
<tr>
<td>PROPELLE SHAFT/DIFFERENTIAL</td>
<td>(C)</td>
</tr>
</tbody>
</table>

**Correction Instructions**

1. Adjust the **engine** center line (1 - 2) and/or **differential** center line (7 - 10) to make them **parallel** to each other and joint angles (A) and (C) **equal**.

2. Adjust the **center lines** of the engine, intermediate shaft, propeller shaft, and differential to make them as **straight** as possible and **reduce** joint angle (A) and (C).

3. Perform the **verification procedures** discussed in Section 3 to ensure the condition has been **corrected**.

**Questions**

1. List what could cause the horizontal angle to change.

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
2. List the components and angle that would be effected.

3. What is the value of using a protractor in this worksheet?

4. What type of vibration would you read on the NVH Analyzer with a horizontal joint angle condition?
Repair Technique:  **Tire Runout Measurement and Phase Matching**

Runout can be one of the causes of tire and wheel vibrations, though not as common as balance. The technician has to be able to determine the **amount of runout**, the **component** causing it and if it can be resolved through phase matching or component replacement.

The following worksheet is designed to provide **experience** in:

- **Measuring** the runout of a tire and rim.
- Using the **radar chart** to determine relative location of the tire and rim runout.
- Determining component **serviceability**.

---

**Radar Chart, Tire and Wheel**

Fig. 4-4
Instruction

1. Mark the tire into twelve equal segments.

2. Use a dial indicator to measure the lateral and radial runout of the tire and rim.

3. Record the readings from the twelve locations on the radar chart for both the tire and rim (attached). Use the “twelve” position on the tire and chart as the “0” point for the dial indicator. Each eleven positions will be plus or minus from that point.

4. Record the readings for the rim using a location on the chart inside the readings for the tire.

5. Draw lines to connect the readings in the twelve positions for the tire and rim.

6. Dismount the tire and remount lining up the lowest position of the rim with the highest position of the tire to achieve the lowest possible total runout.

7. Remeasure the total radial runout and determine serviceability of the tire and wheel.

<table>
<thead>
<tr>
<th></th>
<th>TOTAL RADIAL RUNOUT BEFORE PHASE MATCHING</th>
<th>TOTAL RADIAL RUNOUT AFTER PHASE MATCHING</th>
<th>LATERAL RUNOUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIRE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIM</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Questions

1. Is it possible for a tire to indicate excessive runout and have nothing wrong with the tire? Explain.

2. List the components that could cause the condition in question #1.

3. What is the specification for checking the wheel centering with the hub or axle flange? Where did you find it?

4. What impact would wheel centering have on runout? Which one, lateral or radial?

5. How would you guard against a flat spot effecting your readings? Which readings would be effected, lateral or radial?
Questions (continued)

6. What makes a good _reference or starting point_ when measuring runout?

7. Why is it important to make sure the reference point for the tire and rim measurement are the _same_ on the chart?

8. How is the _high_ and _low_ points of the tire and wheel _determined_ once the radar chart is completed?

9. Can you _predict_ what the total runout will be _after_ phase matching the tire and rim using the information on the completed chart?

10. What is the _value_ of predicting the total runout?
Interior and wind noise complaints are usually not as difficult to repair as they are to find. The difficulty in finding the source of a noise is caused by the many possible transmission paths of the noise. As a result, people sitting in different locations in the vehicle will have different opinions on the location of the noise.

Toyota has published two excellent programs to assist the technician with diagnosing and repair of these conditions.

- Interior Noise  P/N 00401-42856-R92
- Wind Noise  P/N 00401-42968

This worksheet is designed to familiarize you with these programs and the skills required to successfully resolve interior and wind noise complaints.
Instructions

1. Review both the Interior and Wind Noise programs to become familiar with:
   - The contents
   - Diagnostic procedures
   - Repair techniques
   - The specification
   - Service tips
   - Check sheets
   - Body fit standards
   - Materials, tools and equipment

2. Use the diagnostic skills developed in this course, your experience in noise diagnosis and repair and the information above to answer the following questions.

Questions

1. What is the frequency range of wind noise?

2. What are the two conditions that effect wind noise?

3. At what speed does wind noise normally occur?

4. Why do the windows need to be shut?

5. What are the two major vibrating forces of wind noise?

6. What should a visual inspection include for wind noise?

7. What are two important characteristics of the tape used to diagnose the wind noise?
Questions (continued)

8. What are two values of the check sheets in the wind noise program?

9. What is the body fit standard for the gap between the top of the door and the roof line on a Paseo?

10. What is the advantage of having more than one person involved during the road test of a noise?

11. What is the part number for the kit available to repair noise complaints?

12. What is the value of the service tips section in the interior noise program?
Summary  This section completes the information required to successfully resolve most NVH complaints. You should have:

- A strong background in NVH principals and theory
- A diagnostic procedure including
  - Verification of the customer complaint
  - Classification of the symptom
  - A road test procedure with the NVH Analyzer
- A pinpoint diagnosis procedure
- NVH repair techniques

Success in NVH service and repair will require practice honing the skills developed in this course. Practice will provide the experience necessary to quickly resolve NVH complaints the first time and ensure long term customer satisfaction.
# CUSTOMER INTERVIEW SHEET

**INSTRUCTIONS**  
The interview should be conducted and the sheet filled out by personnel trained in NVH diagnosis. Please fill in or check all areas with the appropriate response, enter N/A if it does not apply. The details collected during the interview are critical in successfully resolving the concern.

## CUSTOMER DATA

<table>
<thead>
<tr>
<th>Name:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Telephone #:</th>
<th>RO #:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## VEHICLE DATA

<table>
<thead>
<tr>
<th>Model/Year:</th>
<th>Mileage:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VIN #:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

Is the customer the primary operator of the vehicle?  ○ Yes  ○ No

## NVH DATA

What type of condition is the customer experiencing?  ○ Noise  ○ Vibration  ○ Harshness (ride quality)

Is the condition constant?  ○ Constant  ○ Intermittent

When did it start?  ○ While in Service  ○ Since New  ○ Gradually  ○ Suddenly

○ Other

### NOISE

Describe the Noise:  ○ Squeak  ○ Rattle  ○ Wind Noise

When does the noise seem to be the loudest or most frequent?

Mark the location of the noise on the illustration (reverse side of this form).

### VIBRATION

Where is it felt:

○ Steering Wheel  ○ Floor  ○ Seat  ○ Instrument Panel

○ Brake Pedal  ○ Console  ○ Accelerator Pedal

○ Shifter  ○ Body  ○ Mirrors  ○ Clutch Pedal

Describe the vibration:

○ Vertical  ○ Horizontal  ○ Rotational

○ Other:

### HARSHNESS (Ride Quality)

Where do you experience it?

When do you experience it?

Has the vehicle ever been damaged?  ○ Yes  ○ No  If so, please indicate where on the illustration.

Is there any relevant service history?  ○ Yes  ○ No  If so, please describe:

Has there been any accessory installation?  ○ Yes  ○ No

Is the vehicle used for towing or to carry any cargo or equipment?  ○ Yes  ○ No
OPERATING CONDITION

When does the condition occur?  ○ Starting  ○ Idling  ○ Cruise  ○ Coasting  ○ Other __________

Vehicle Speed (MPH): ____________________________  Engine Speed (RPM): ____________________________

○ Cornering Left  ○ Cornering Right  ○ Acceleration  ○ Deceleration

○ Braking  ○ Clutch Engagement  ○ Other __________

Accessories:  ○ HVAC  ○ 4WD  ○ Audio  ○ Other _________________

Engine Temperature:  ○ Cold  ○ Normal  ○ Hot

Road Conditions:  ○ Highway  ○ Suburb  ○ City

Road Surface:  ○ Asphalt  ○ Dirt/Off Road  ○ Concrete with Expansion Joints

○ Undulating  ○ Other Irregularities

Explain: ____________________________________________

WEATHER CONDITIONS

Temperature: _____ °F  ○ Clear  ○ Rain  ○ Ice/Snow  ○ Wind

○ Other ____________________________________________

ADDITIONAL INFORMATION

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
## SPECIFICATION CHART

<table>
<thead>
<tr>
<th>ITEM</th>
<th>SPECIFICATION</th>
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</thead>
<tbody>
<tr>
<td>Tire runout</td>
<td></td>
</tr>
<tr>
<td>Radial</td>
<td>1.0mm (0.039in.) max.</td>
</tr>
<tr>
<td>Lateral</td>
<td>1.2mm (0.047in.) max.</td>
</tr>
<tr>
<td>Wheel rim runout</td>
<td></td>
</tr>
<tr>
<td>Radial</td>
<td>0.5mm (0.019in.) max.</td>
</tr>
<tr>
<td>Lateral</td>
<td>0.5mm (0.019in.) max.</td>
</tr>
<tr>
<td>Hub runout</td>
<td></td>
</tr>
<tr>
<td>Radial</td>
<td>0.05mm (0.002in.) max.</td>
</tr>
<tr>
<td>Lateral</td>
<td>0.05mm (0.002in.) max.</td>
</tr>
<tr>
<td>Hub to wheel centering clearance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.1mm (0.004in.) max.</td>
</tr>
<tr>
<td>Wheel rim mating surface flatness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.1mm (0.004in) max.</td>
</tr>
<tr>
<td>Differential companion flange runout</td>
<td></td>
</tr>
<tr>
<td>Vertical</td>
<td>0.05mm (0.002in.) max.</td>
</tr>
<tr>
<td>Horizontal</td>
<td>0.05mm (0.002in.) max.</td>
</tr>
<tr>
<td>Differential</td>
<td></td>
</tr>
<tr>
<td>Ring gear runout</td>
<td>0.07mm (0.003in.) max.</td>
</tr>
<tr>
<td>Ring gear backlash</td>
<td>0.13 - 0.18mm (0.005 - 0.007in.)</td>
</tr>
<tr>
<td>Center bearing flange runout</td>
<td>0.05mm (0.002in.) max.</td>
</tr>
<tr>
<td>Universal joint play</td>
<td>0.05mm (0.002in.) max.</td>
</tr>
<tr>
<td>Propeller shaft runout</td>
<td>0.8mm (0.032in.) max.</td>
</tr>
<tr>
<td>Torque converter sleeve runout</td>
<td>0.3mm (0.012in.) max.</td>
</tr>
<tr>
<td>Drive plate runout</td>
<td>0.2mm (0.008in.) max.</td>
</tr>
<tr>
<td>Brake Rotor</td>
<td></td>
</tr>
<tr>
<td>Runout</td>
<td>0.1mm (0.004in.) max.</td>
</tr>
<tr>
<td>Thickness</td>
<td>0.01mm (0.0004in.) max.</td>
</tr>
<tr>
<td>Brake drum runout</td>
<td>0.1mm (0.004in.) max.</td>
</tr>
<tr>
<td>Axle hub and shaft</td>
<td></td>
</tr>
<tr>
<td>Runout</td>
<td>0.05mm (0.002in.) max.</td>
</tr>
<tr>
<td>Surface flatness</td>
<td>0.05mm (0.002in.) max.</td>
</tr>
</tbody>
</table>
Appendix E

GLOSSARY OF TERMS

**A**

**Acceleration** - The rate in change of velocity with respect to time.

**Accelerometer** - A mechanical device that senses vibration (acceleration) and sends an electrical signal to a signal conditioner in proportion to the acceleration.

**Amplitude** - The quantity used to express the level or magnitude of a vibration. When expressed in dBg (Decibels g) it relates closely to what the customer feels.

**Aspect ratio** - A ratio of the section height of a tire over the section width of a tire. Another term is series, a 75 series tire is 75% as tall as it is wide.

**Attenuate** - To reduce in force, value or amount; weaken.

**B**

**Beating** - A cyclical vibration or sound at in an operating vehicle that is the result of two vibrations or sounds of similar frequency.

**Booming Noise** - A constant sound or pressure on the ears of relatively low frequency (30 - 200 hz).

**Buzz** - A term used to describe a sound similar to a ballast in a fluorescent light.

**C**

**Centrifugal Force** - The force or pull from the center of a rotating object.

**Component** - (see order)

**CPS** - Cycles Per Second

**Cycle** - A single complete execution of a periodically repeated event. It is often timed.

**D**

**Dampen** - To decrease the amplitude of a vibration or sound. To eliminate or progressively diminish oscillations. A means of dissipating vibration energy in a vibrating system.

**Data Link** - A communication link between a vehicle computer and a diagnostic tester.

**Deceleration** - Slowing of an object velocity. i.e. Slowing of a vehicle when the accelerator is released with engine compression adding to the resistance and no brake application.

**Decibel (dB)** - A unit of measurement used to compare the quantity of power or intensity of sound level to other quantities. The comparison is expressed logarithmically which is similar to what humans sense.

**Drone** - A continuous low dull humming or buzzing sound.

**Dynamic Damper** - A device attached to a vibrating system (with rubber or a spring) that changes the natural frequency and resonant point of the vibrating system. It moves independently, introducing a second vibration of opposite phase. The result is two vibrations of lower amplitude with different resonant points than the original vibration. The advantage is that the new resonant points will likely be outside the normal vibrating forces in the vehicle.
**Forced vibration** - A sustained vibration of a vibrating system from a continuing, cyclical, external force. The system will vibrate at the same frequency as the external force.

**Free vibration** - A vibration that continues after the external force has been removed.

**Frequency** - The number of times a specific phenomenon occurs within a specified interval. The number of complete cycles occurring in a second (Hertz Hz).

**Harshness** - Vibration generated by impact force acting on the tires and transmitted through the suspension system to the car body as the vehicle moves across road irregularities.

**Hertz (Hz)** - A unit used in the measurement of frequency. 1 Hertz (Hz) = 1 Cycle Per Second (CPS) of a vibrating or rotating object.

**Howl** - A low frequency sound similar to a differential with a bad bearing.

**Hz** - Hertz (Cycles Per Second)

**Imbalance** - Out of balance; unequal distribution of weight around a rotating object or component, causing a vibration.

**Judder** - A term commonly used to describe a low frequency vibration on a clutch on engagement. 10-20Hz

**Lateral force variation (LVF)** - A measure of tire uniformity in variations of lateral force.

**Lateral runout** - Deviation from side to side of a rotating component. Measured with a dial indicator parallel with the axle.

**Mass Damper** - A mass fixed to a component to change the natural frequency of the component.

**Natural frequency** - The frequency that a vibrating system will vibrate when set into free vibration.

**Noise** - A term used to describe a sound that is unpleasant to the senses.

**NVH** - Noise, Vibration and Harshness

**Order** - Vibrations that are multiples of other existing vibrations. For example a second order vibration is twice the frequency of the first order. A third order vibration is three times the frequency as the first.

**Oscillation** - To move between alternate extremes in a definable period of time.
Phase - A quantity to indicate position within a period of periodical event. The relationship of one rotating component to another at the same frequency, such as the position of two U-joints on the same shaft or the position of the high and low spots of a tire and rim.

Phenomenon - An occurrence that is directly perceptible by the senses.

Pitch - An auditory sensation that enables one to locate a sound on a scale from low to high. It is determined by frequency the higher the frequency the higher the pitch.

Pulsation - A low frequency, periodic throbbing that can be heard or felt.

Radial force variation (RFV) - A measure of tire uniformity in variation of load acting toward the tire center.

Resonance - A phenomenon of maximum amplitude or level caused by the sum of energy when the natural frequency and the frequency of the vibrating force are the same.

Road Test - Operation of a vehicle under conditions designed to recreate the complaint condition.

Roughness - A harsh irregular vibration, similar to the vibration of an engine with a miss-fire.

Rumble - A low, heavy, muffled, continuous reverberating sound. Similar to thunder.

Radial Runout - Deviation in the plane of rotation of a rotating component. (eccentricity) Measured with a dial indicator mounted perpendicular to the axle.

Shake - Refers to a major vertical and/or lateral vibration of the body, seats and steering wheel 10-30Hz. (vertical and lateral vibrations may occur alternately)

Shimmy - A low frequency vibration of the steering wheel along the direction of rotation. 5-15 Hz

Static - Having no motion, at rest.

Tolerance - Leeway for variation from a standard. Deviation from a specified value of a structural dimension.

Transmission System - The path for a noise or vibration to travel from the source to the occupants of a vehicle.

Vibration Analyzer - A tool used to sense and display vibration. The vibrations are displayed according to frequency and amplitude.

Vibrating Force - An external force on a vibrating system that puts the system into motion.

Vibrating System - A group of components that respond to an external force and produce a vibration or sound that can be sensed by the occupants of a vehicle.

Working Angle - The angle formed by two rotating components such as a transmission and a propeller shaft.
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