Section 1

FUNDAMENTALS OF NOISE, VIBRATION, AND HARSHNESS

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

Introduction
Continued

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.**

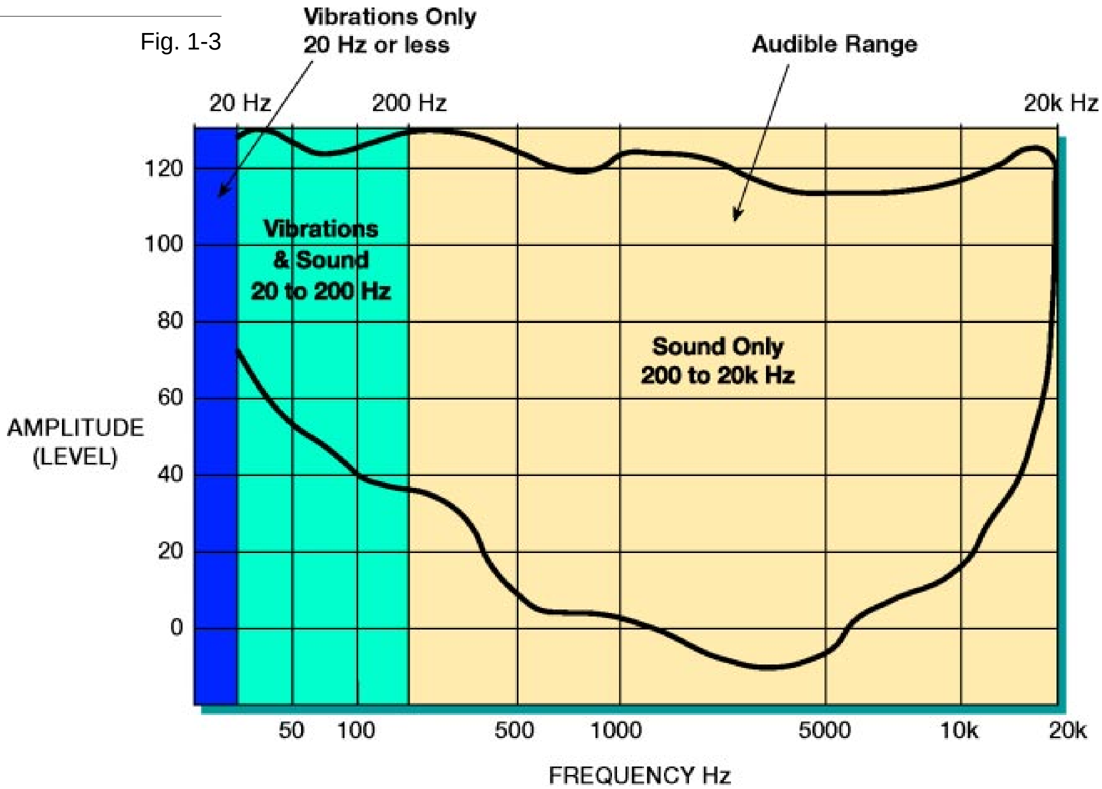
A sound is a vibration (pressure fluctuation) of the air.

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

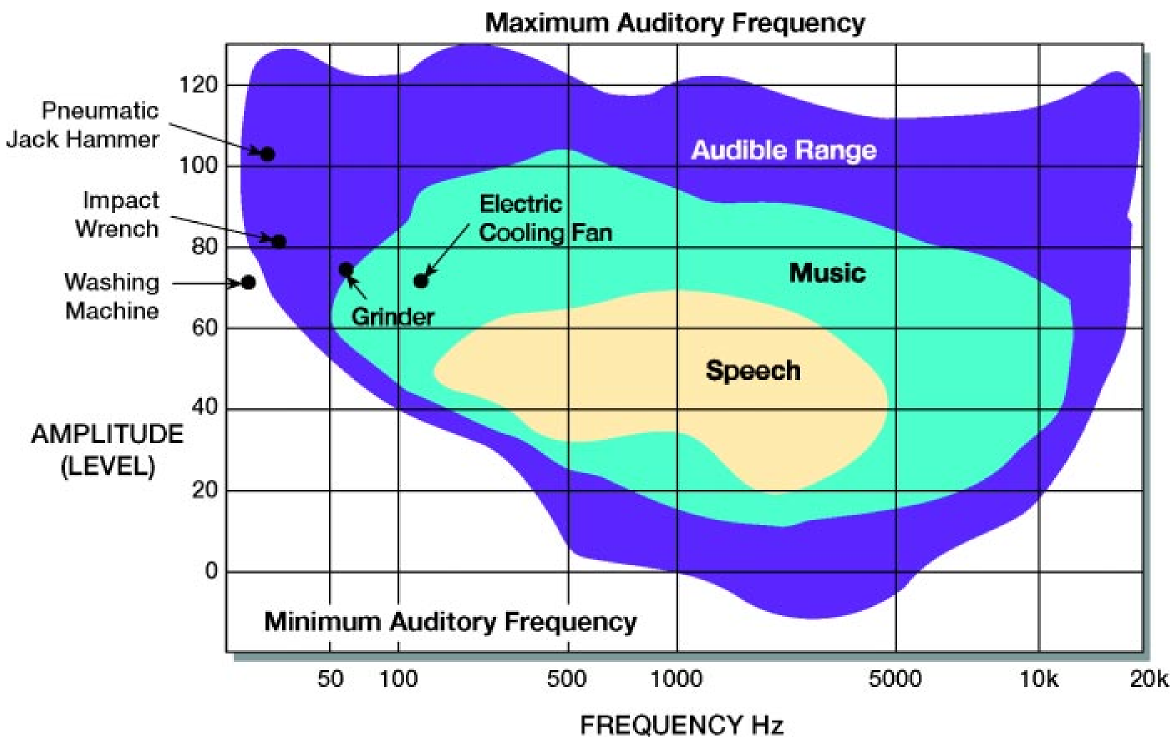
Frequency Ranges of Vibration and Sound

Fig. 1-3



Audible Range

Fig. 1-4



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:

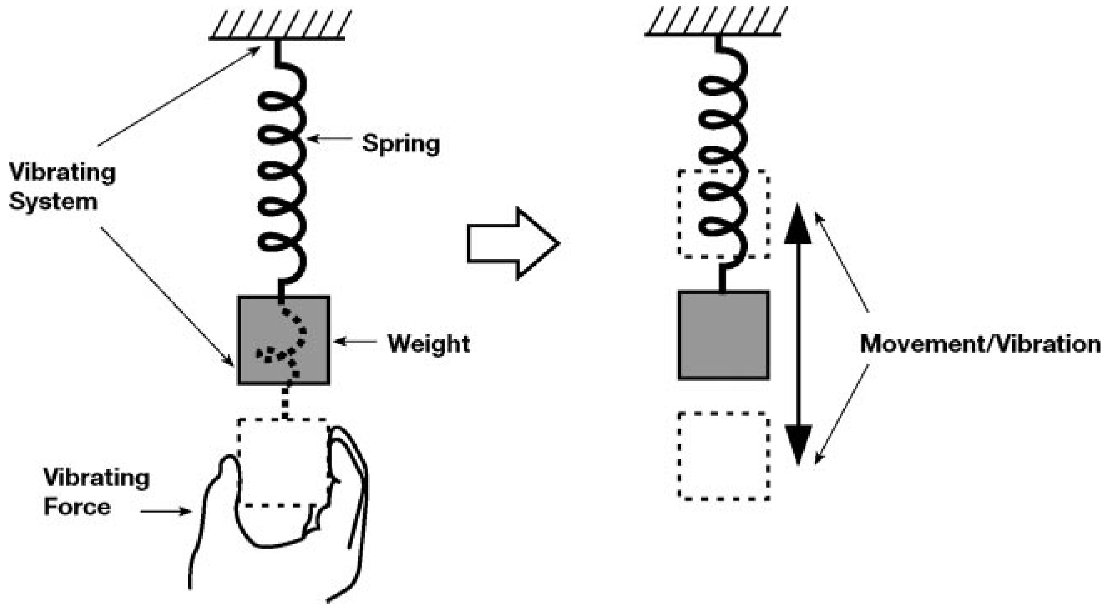
- A string on a musical instrument
- A bell
- A tuning fork

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

Fig. 1-5



Vibration
Continued

For example:

A vibrating system in a vehicle is the suspension.

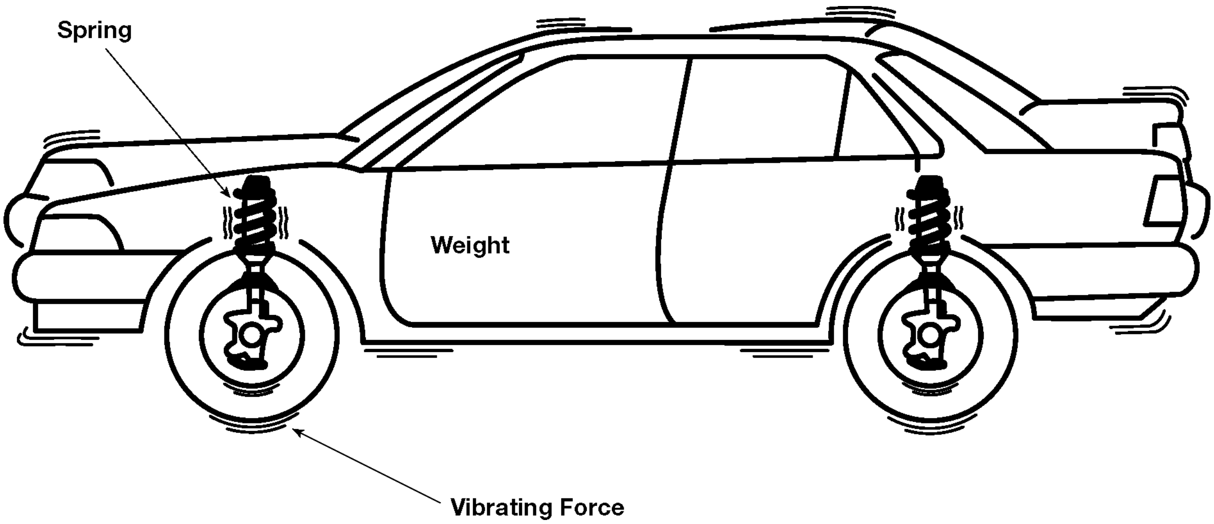
- The spring on the vehicle is similar to the spring on the model.
- The weight of the vehicle is similar to the weight on the model.
- Bumps in the road are the external or vibrating forces that start the vehicle into motion.

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.

Vehicle Movement without Shocks

Fig. 1-6



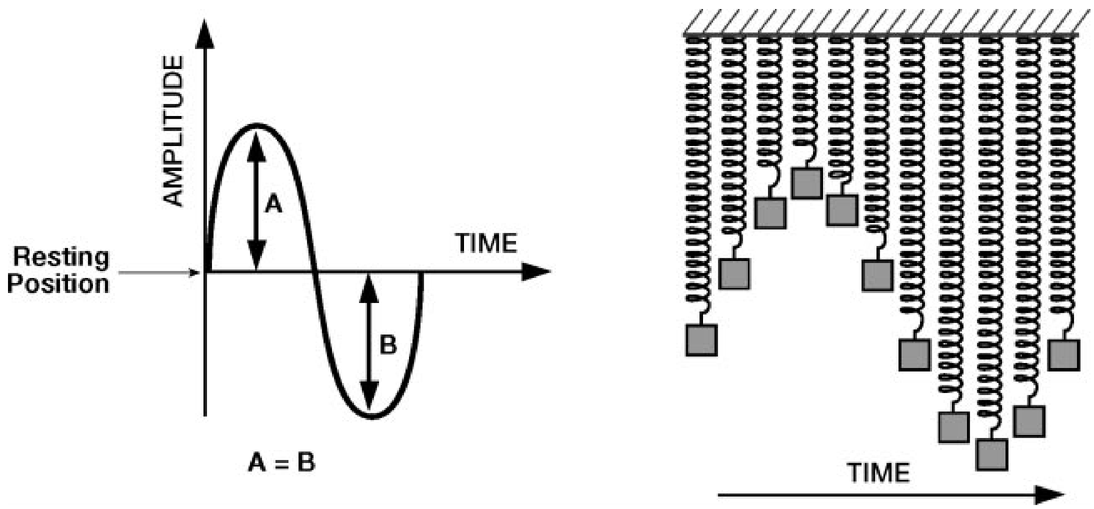
Oscillation is another term used to describe the movement of a vibration. When something oscillates it moves back and forth around a common point.

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

Fig. 1-7



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.

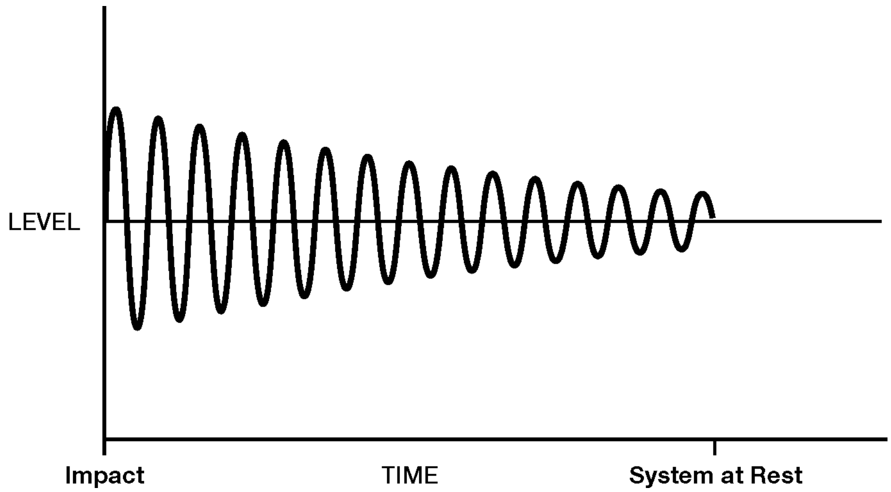
A = B

Cycle
Continued

The movement/vibration will continue until the energy in the system is dissipated and the system is at rest.

Dissipation of Energy from a Single Impact

Fig. 1-8



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)

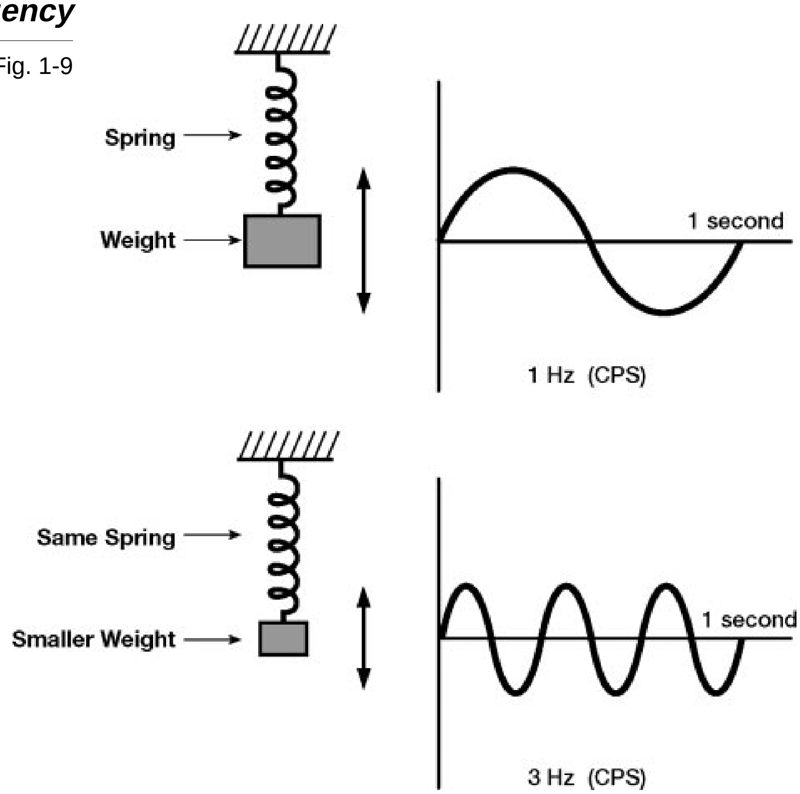
Frequency

The number of **cycles in one second is the frequency** of the vibration.

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

Frequency

Fig. 1-9

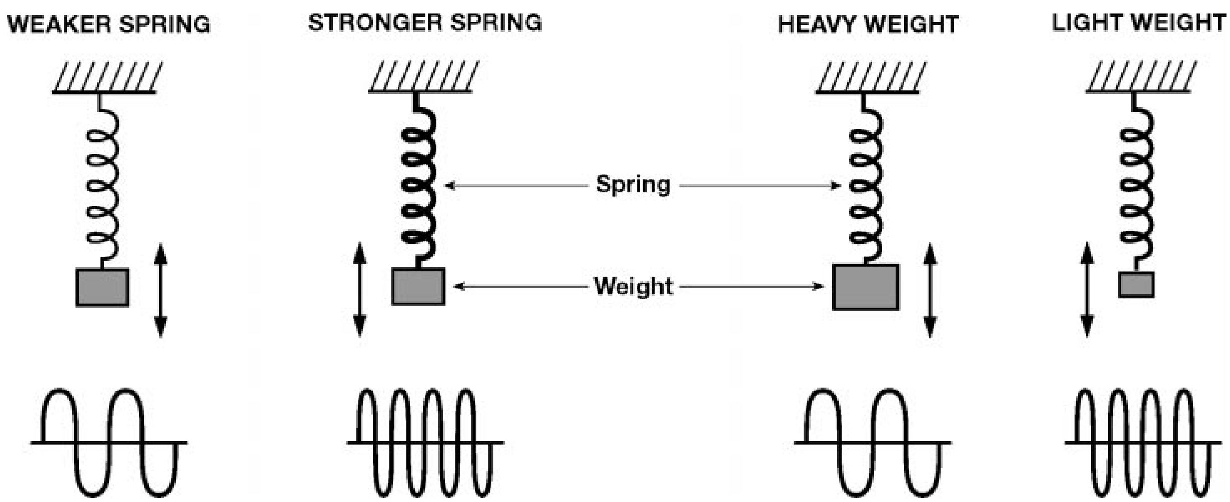


The number of cycles in a second or the frequency (Hz) can be changed by changing the vibrating system. If the strength of the spring is changed or the size of the weight is changed the frequency will change. (All other aspects of the vibrating system unchanged)

- 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

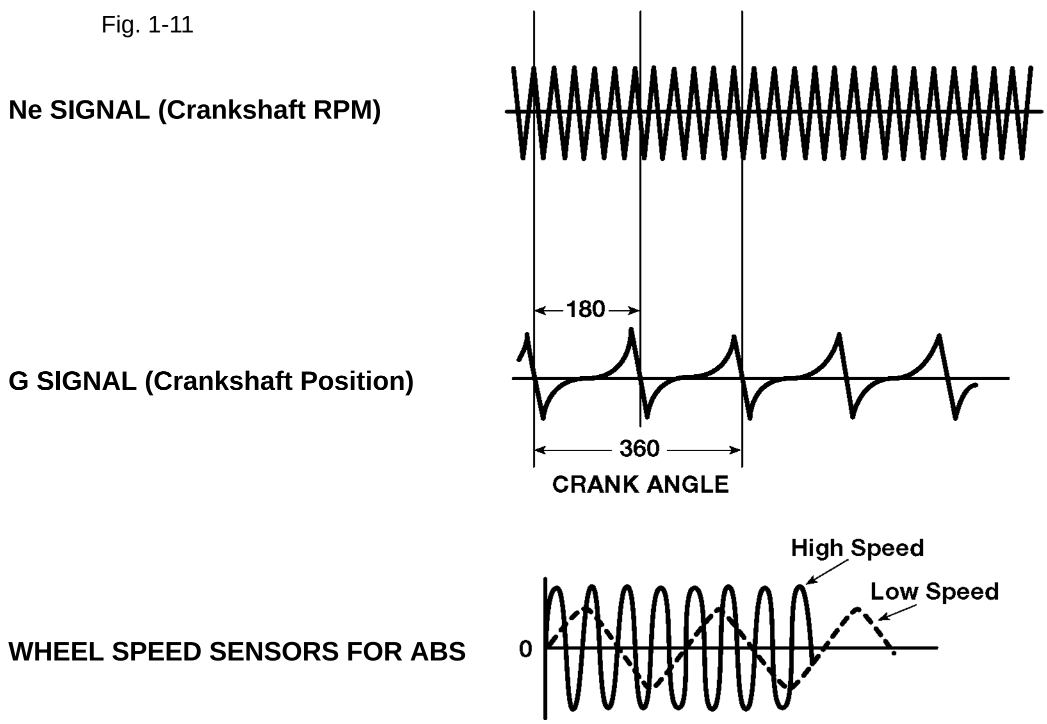
Vibration Characteristics

Fig. 1-10



Sensors Signal

Fig. 1-11



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.

RPM ○ 60 sec = CPS or Hz

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

3000 RPM ○ 60 sec = 50 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.

Hz x 60 sec = 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)

Engine @ **3000 RPM ○ 1 = 3000 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.)

Engine @ **3000 RPM ○ 0.783 = 3831.42 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)

Driveline @ **3831.42 RPM ○ 4.272 = 896.87 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.

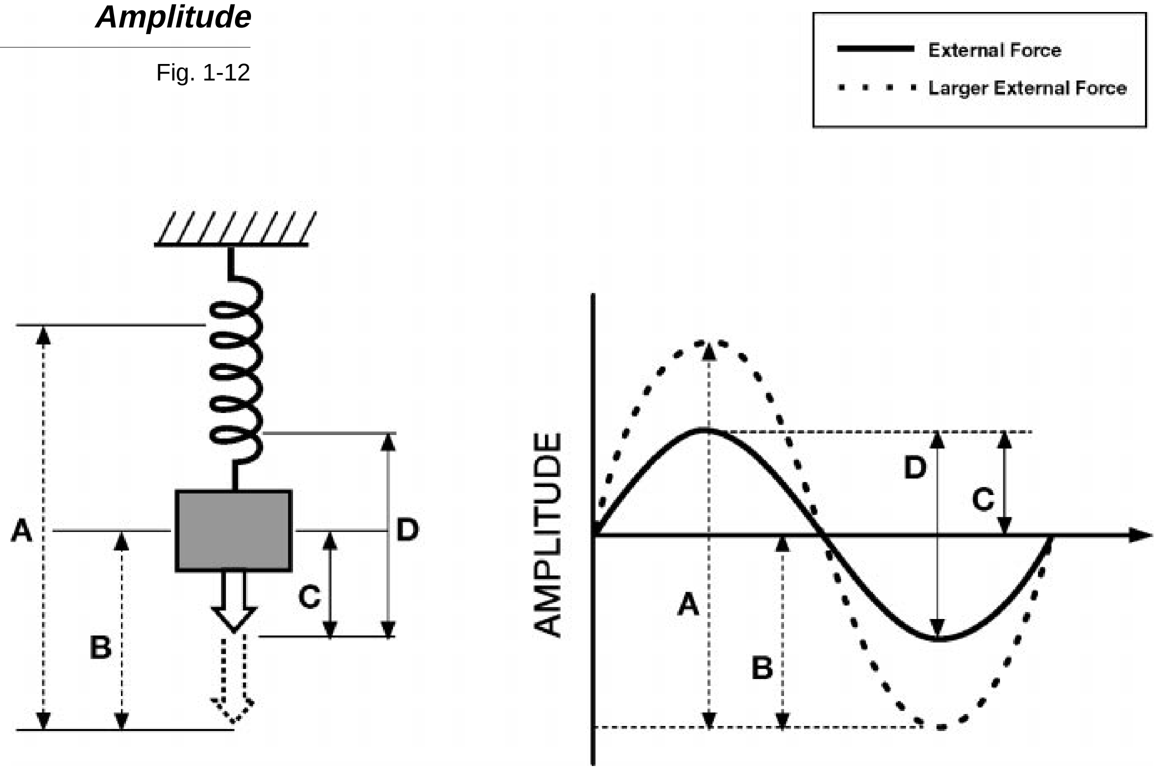
Amplitude is the **size of the wave** and is measured two ways.

- 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.

Amplitude

Fig. 1-12



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

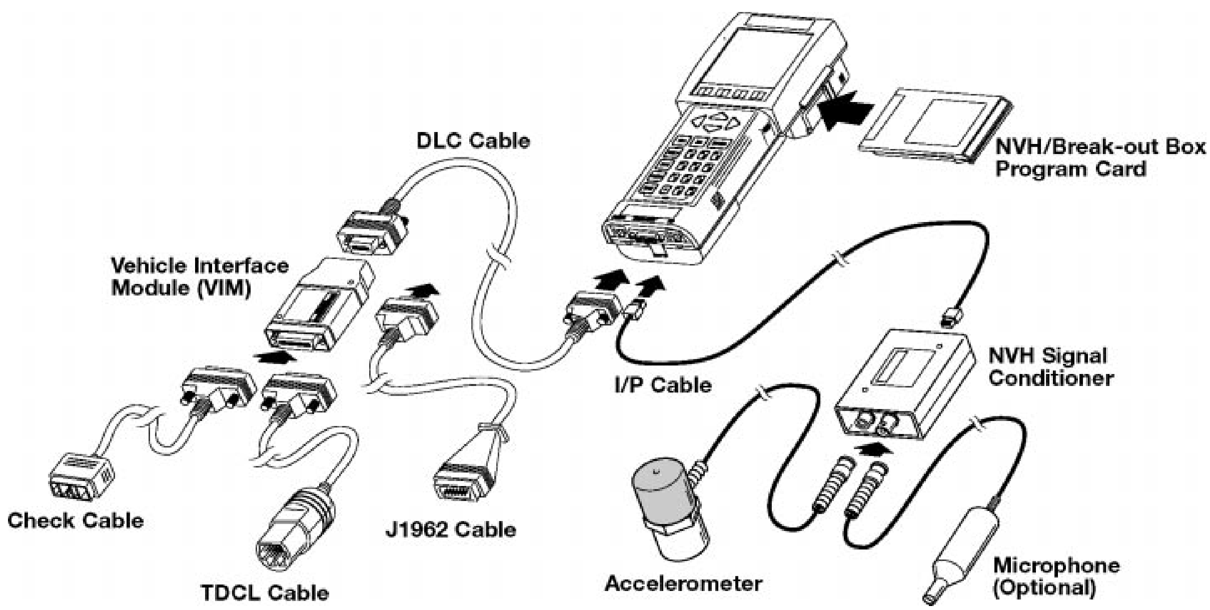
- Amount of energy/amplitude(dBg) - which indicates the level of the vibration the customer feels

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)

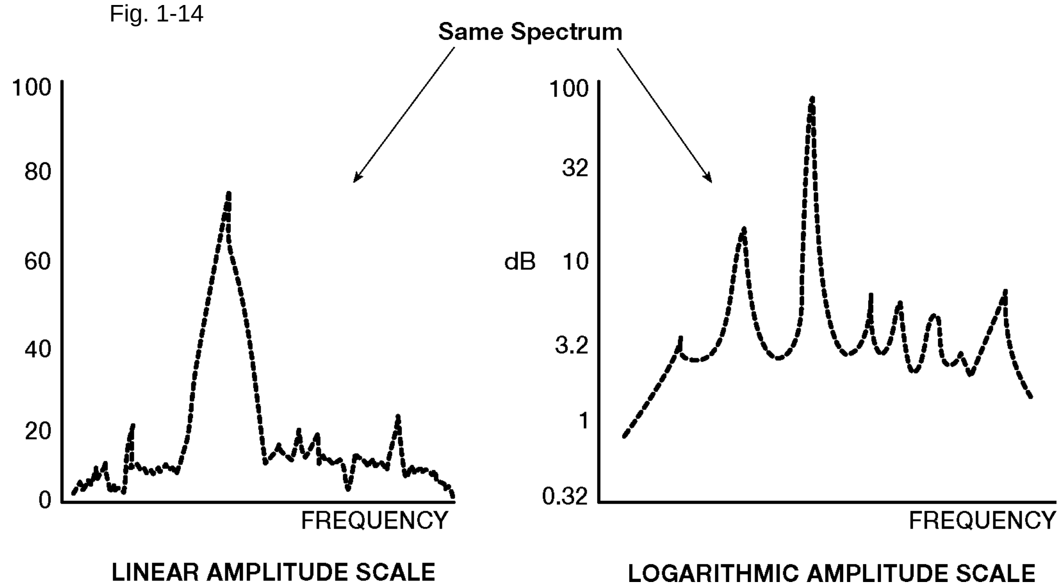
The dB is the unit of measurement related to the level or intensity of what we hear. It is a mathematical calculation (logarithm) of a vibrating force that produces a sound. It is useful to associate the level or amplitude of the vibration to the **level sensed by the customer.**

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.

dB (DECIBEL)

Fig. 1-14



- 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

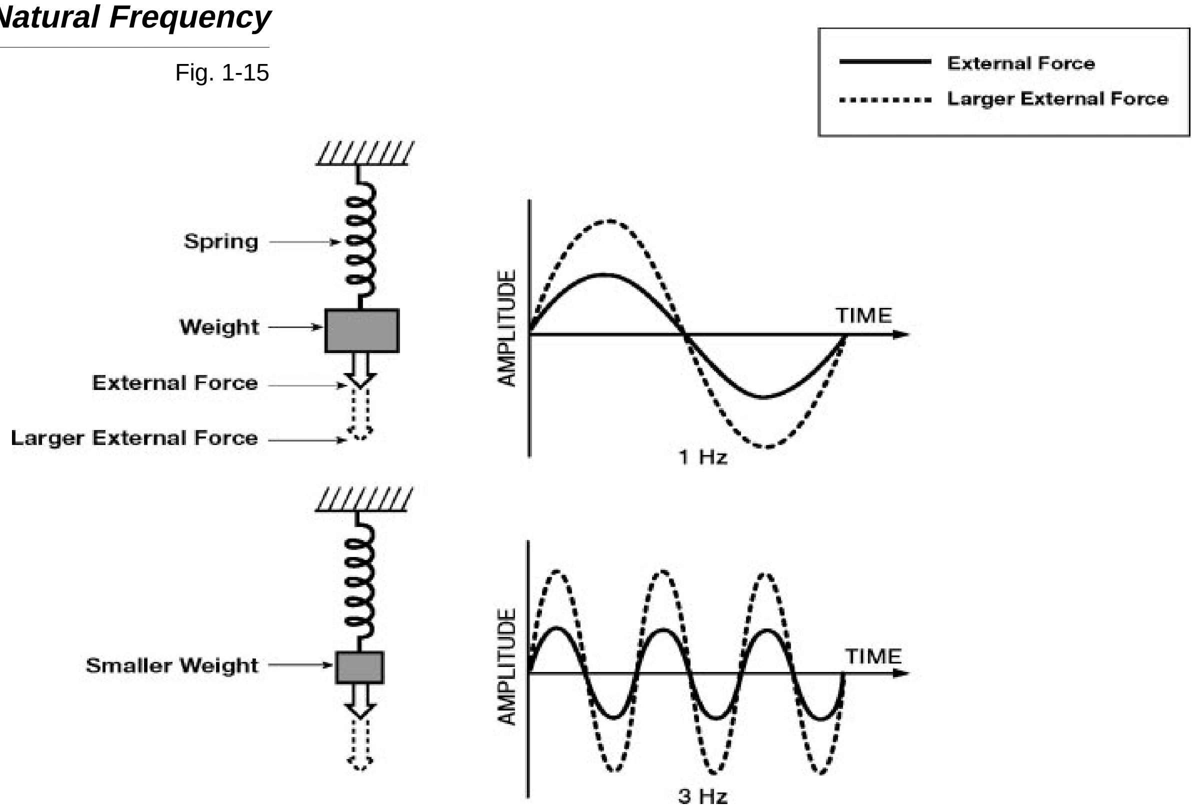
All vibrating systems have a **specific vibrating frequency** unique to that system design. This frequency is called the **natural frequency**.

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**.

Natural Frequency

Fig. 1-15



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.

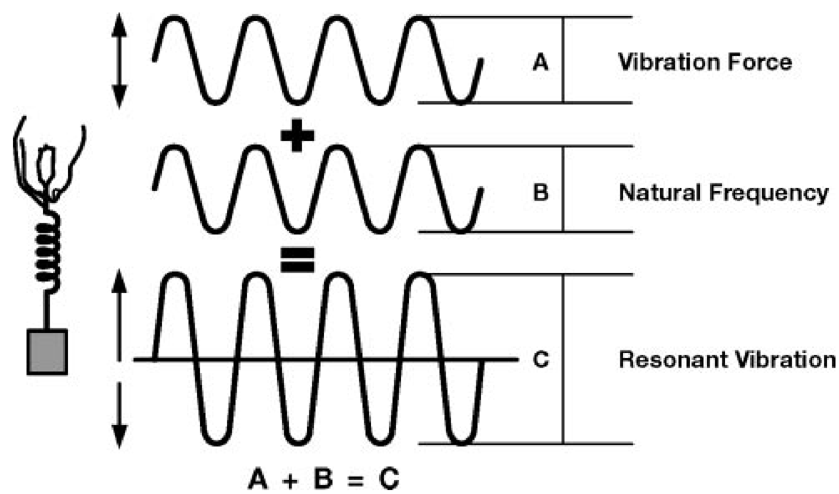
Resonance

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.

Resonance

Fig. 1-16

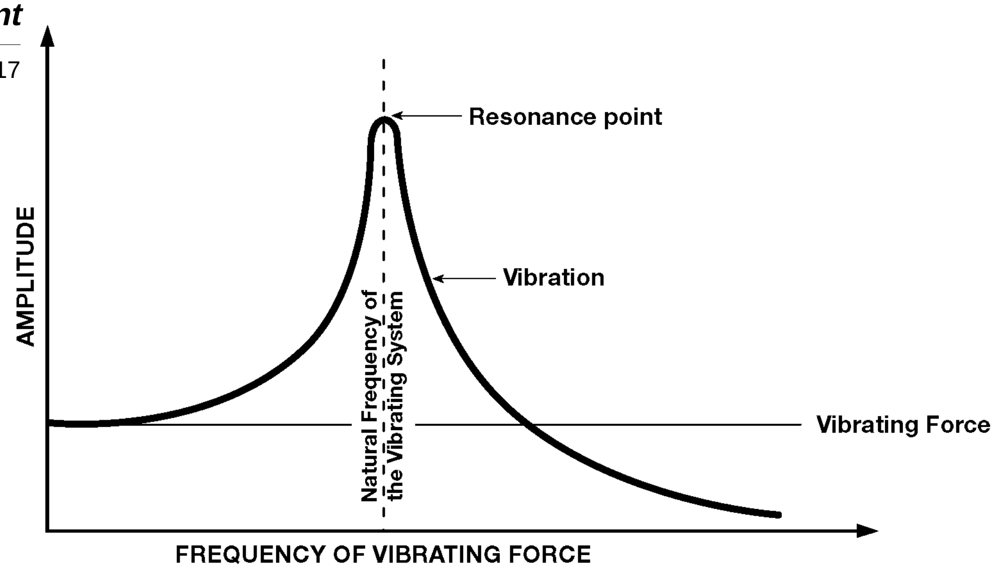


The frequency (Hz) at which this occurs is the **"resonance point"**.

The amplitude (dBg) of the vibrating system increases dramatically when the resonance point is reached.

Resonance Point

Fig. 1-17



Resonance
Continued

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.

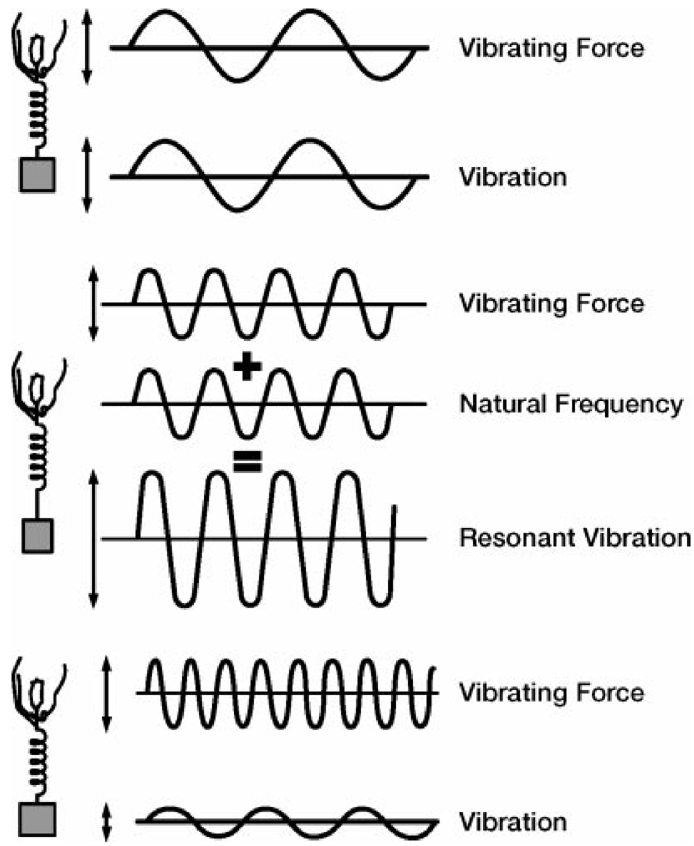
Varying the Frequency to Modify Resonance

Fig. 1-18

Vibrating Force Below the Natural Frequency

Vibrating Force Equal to the Natural Frequency

Vibrating Force Above the Natural Frequency



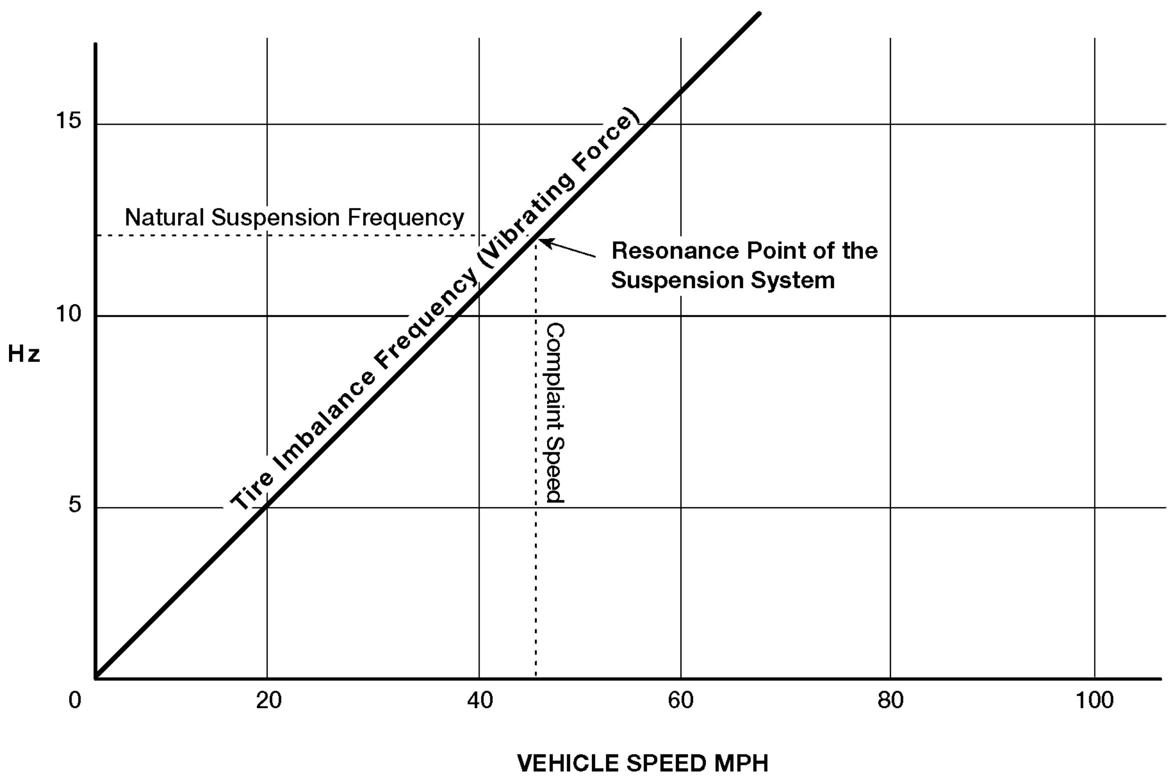
Resonance
Continued

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 Graph

Fig. 1-19



Resonance
Continued

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.

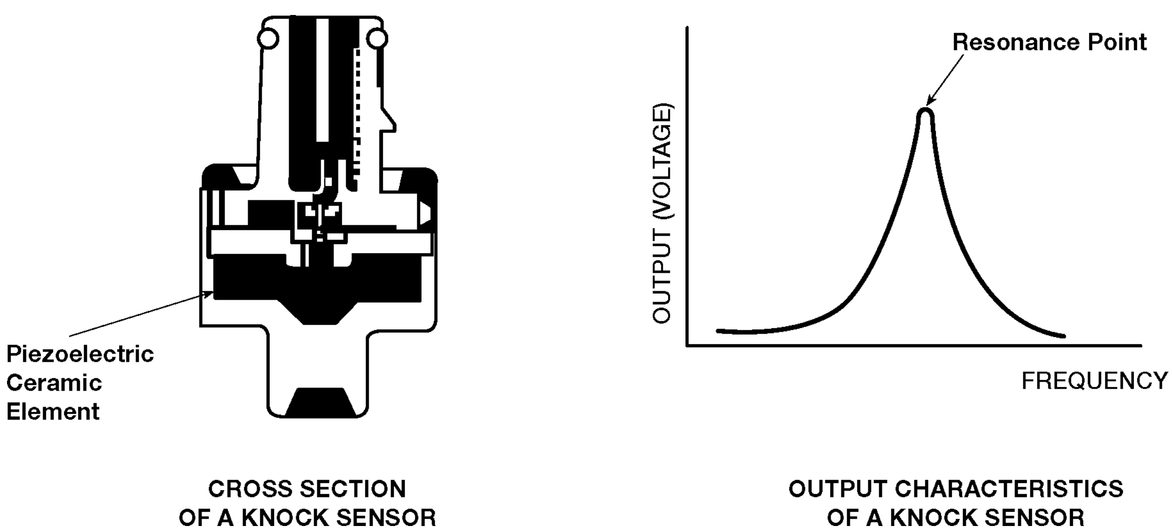
The amplitude of the vibration sensed increases sharply due to the resonance of the element.

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.

Knock Sensor

Fig. 1-20



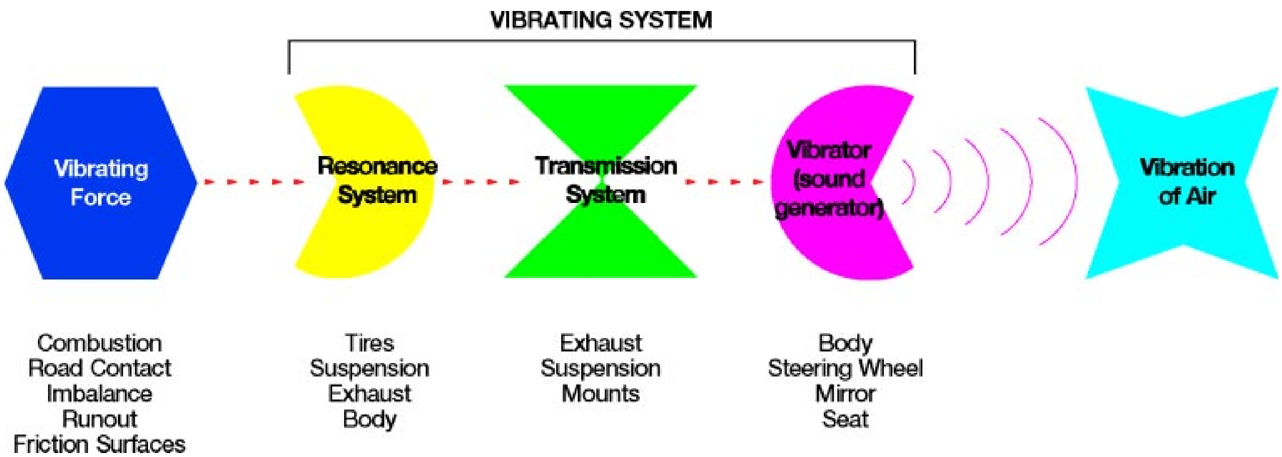
Transmission of Vibrations and Sounds

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 Sound

Fig. 1-21



Transmission of Vibrations and Sounds
Continued

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.

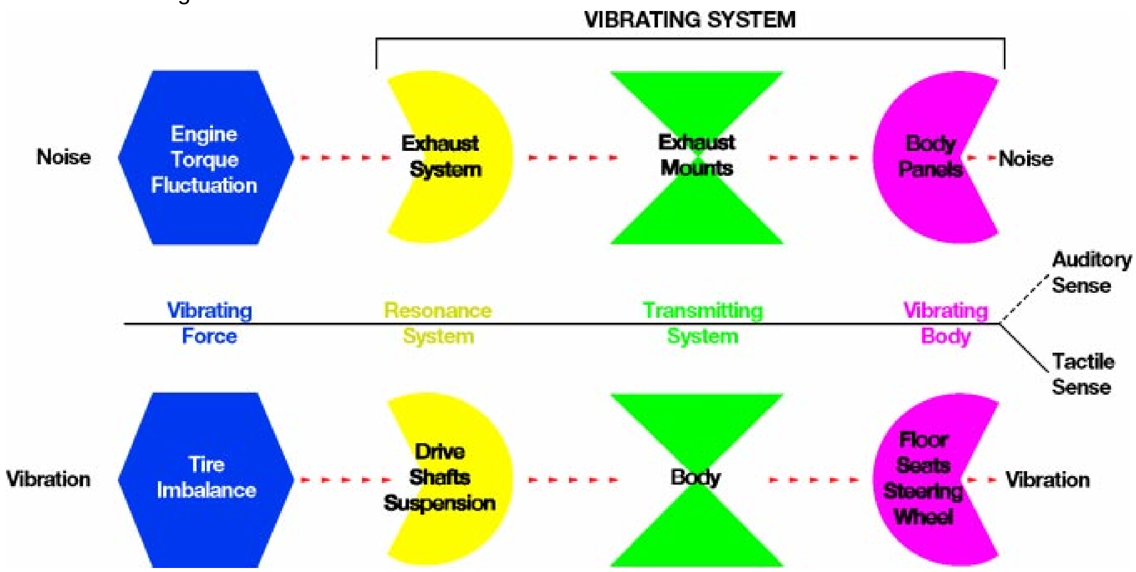
Examples of a vibrator (sound generator) are:

- 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

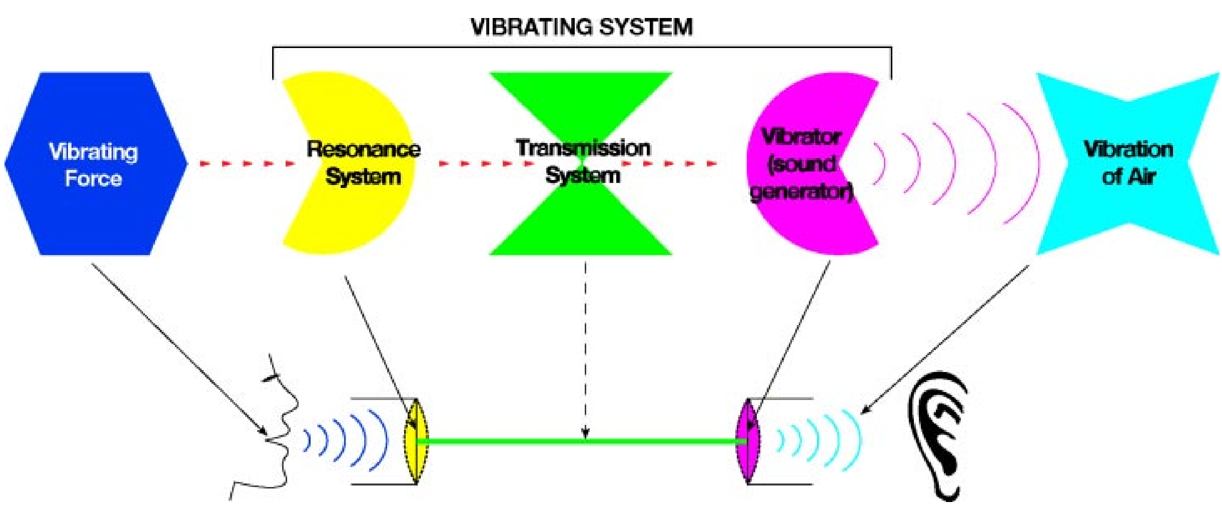


Preventing Vibrations and Sounds

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.

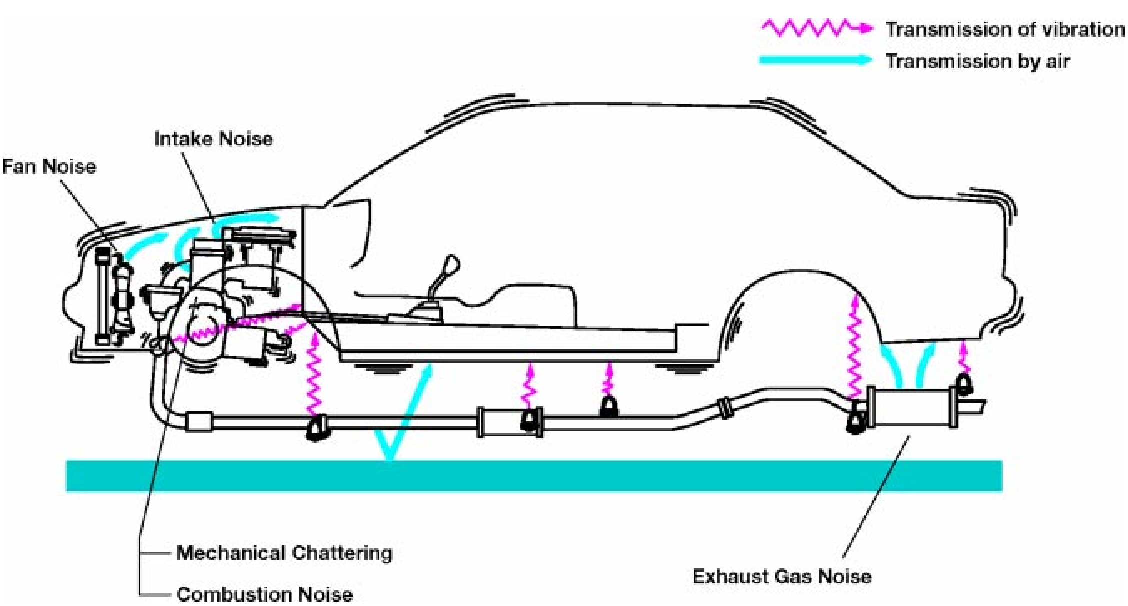
For example:

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

Engine Vibration/ Noise Transmission

Fig. 1-24



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

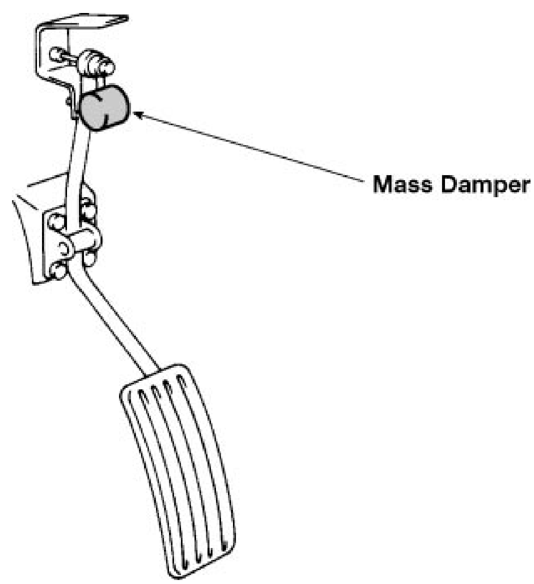
Engineers can modify a vibrating system during the design of a vehicle with the use of **mass or dynamic dampers**.

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

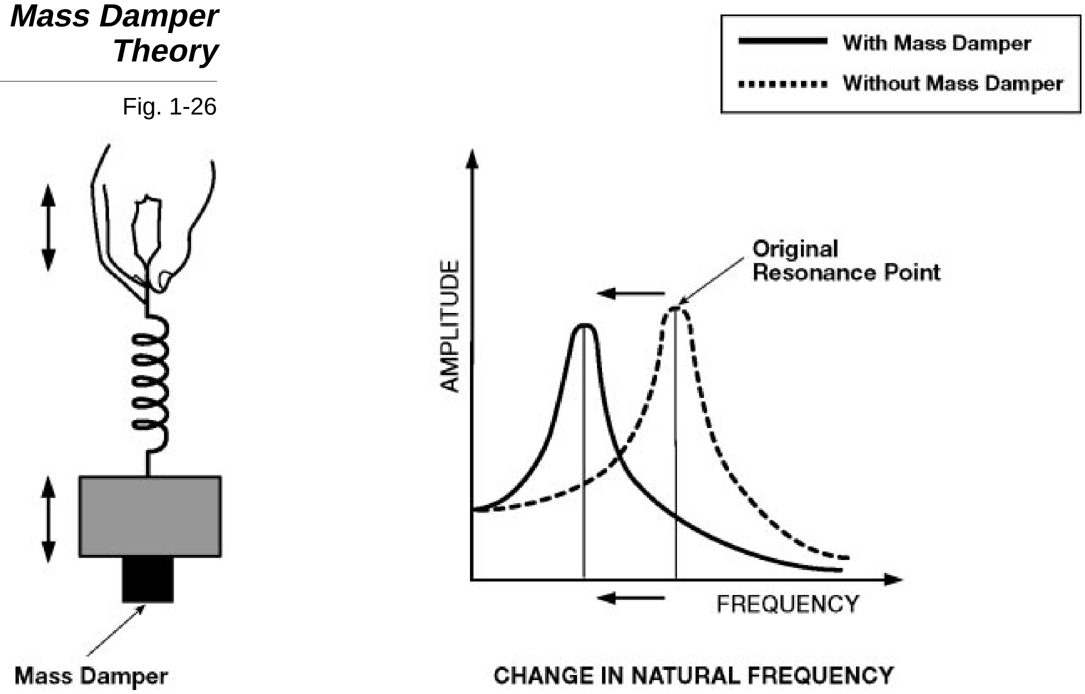
Mass Damper

Fig. 1-25



Mass Damper Theory

Fig. 1-26



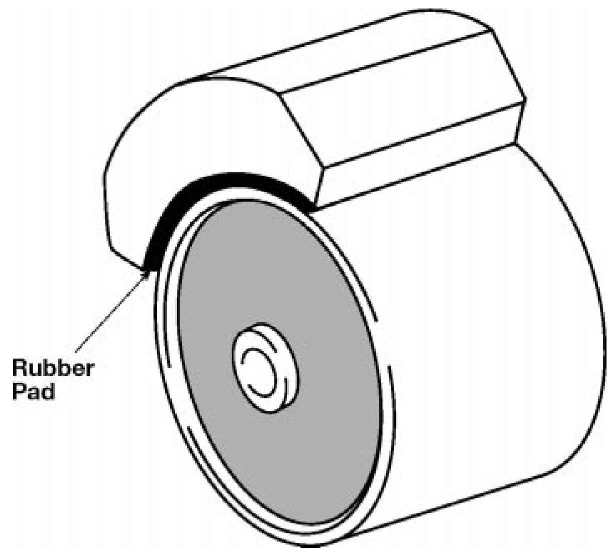
Dampers
Continued

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.

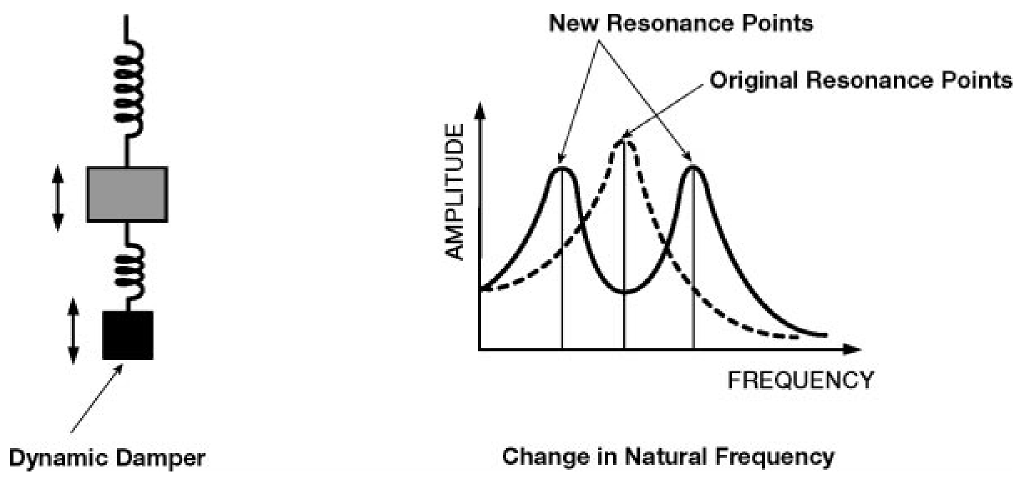
Dynamic Damper

Fig. 1-27



Dynamic Damper Theory

Fig. 1-28



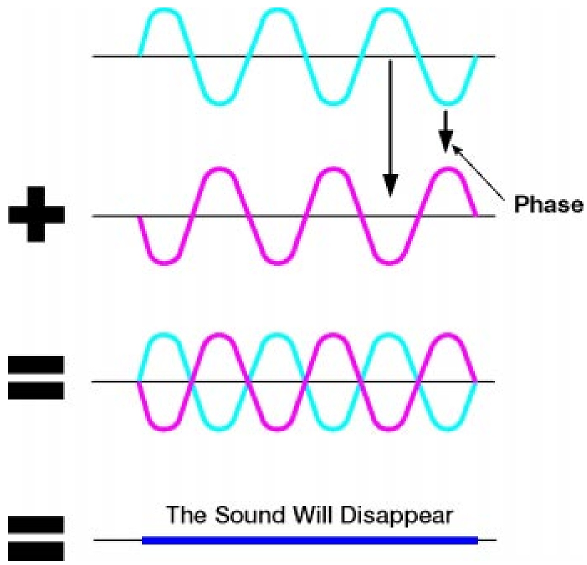
Additional NVH Phenomena

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



Beating/ Phasing/ Growl

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.

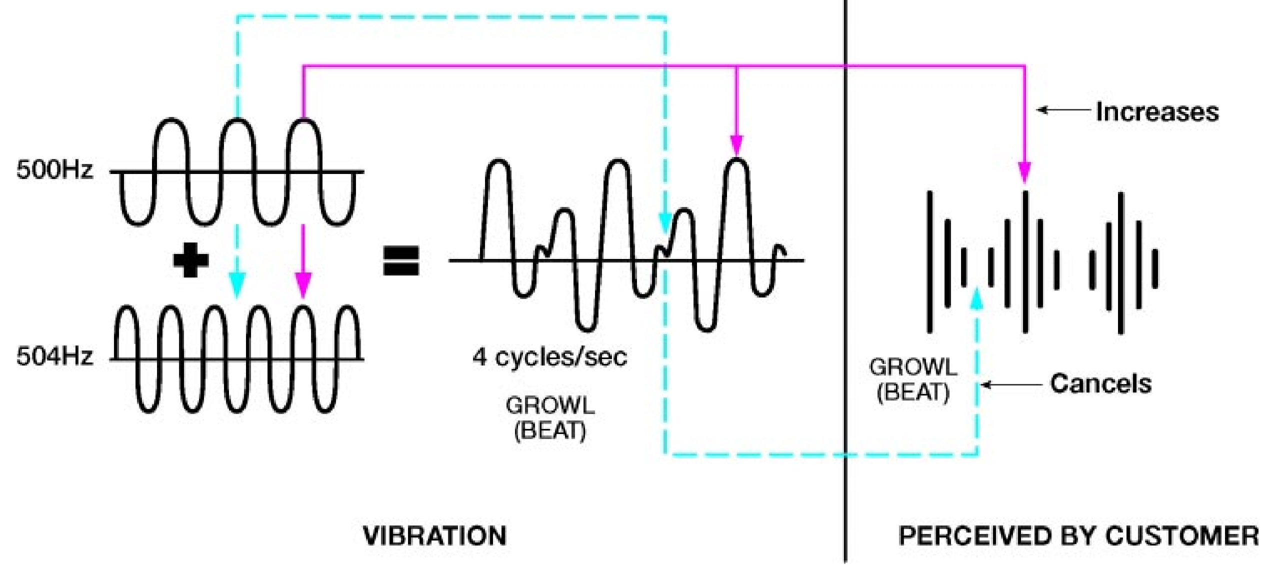
The resulting wave creates a sound called **beating**, which is associated with a vehicle having more than one tire out of balance. Tires are not always the same size and will rotate at slightly different speeds (Hz).

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



Notes

Order A **single** vibrating force may generate **more than one** vibration.

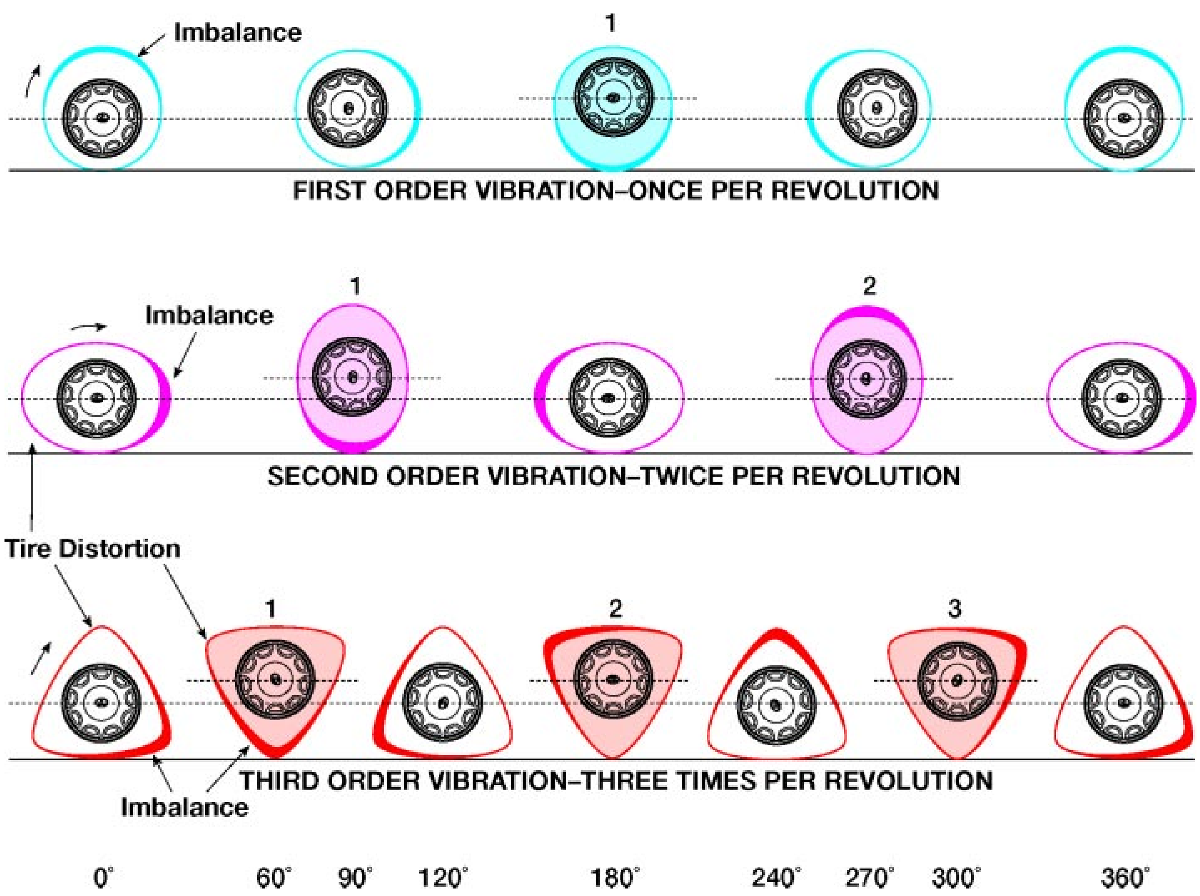
For example:

> 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.

Tire Frequencies

Fig. 1-31



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.

Order
Continued

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.

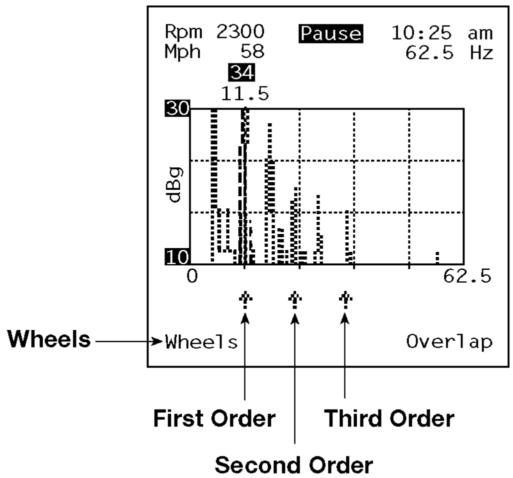
This second vibration is caused by a second bump in the tire as a result of the change in shape. It is usually smaller in amplitude than the first order vibration. This is called the **second order** or second component vibration.

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).

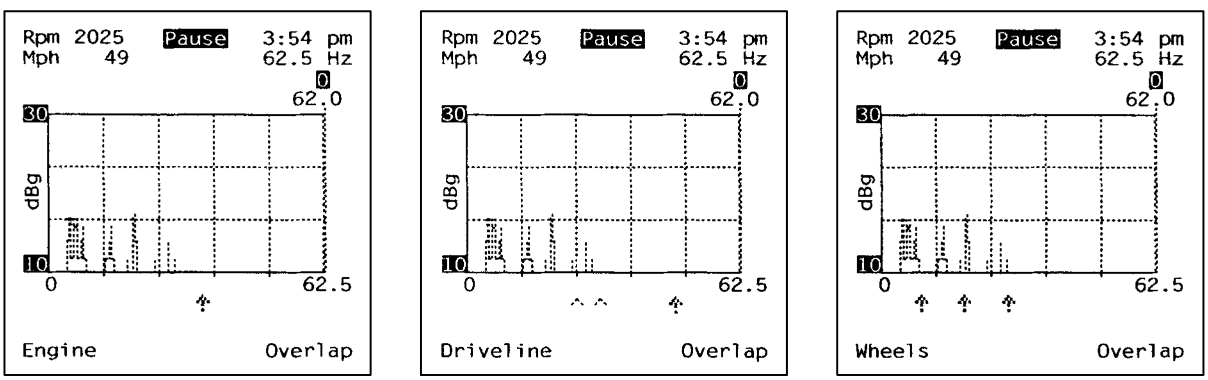
For example:

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

4Runner

Fig 1-37



ENGINE **DRIVELINE** **WHEELS**

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.

Order
Continued

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.

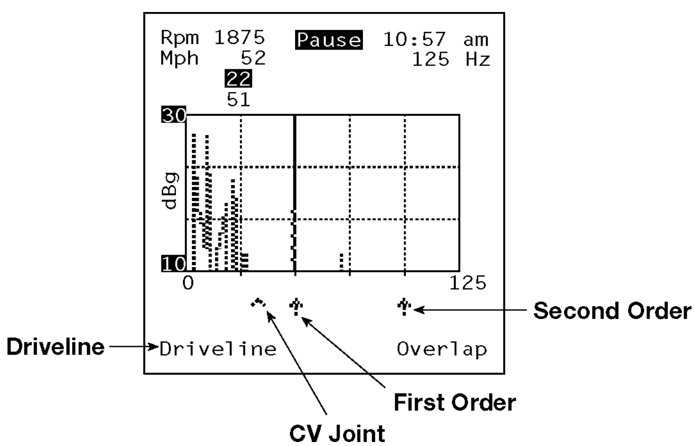
Driveline concerns relating to U-joints are caused by:

- 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.

Driveline Vibrations

Fig. 1-33

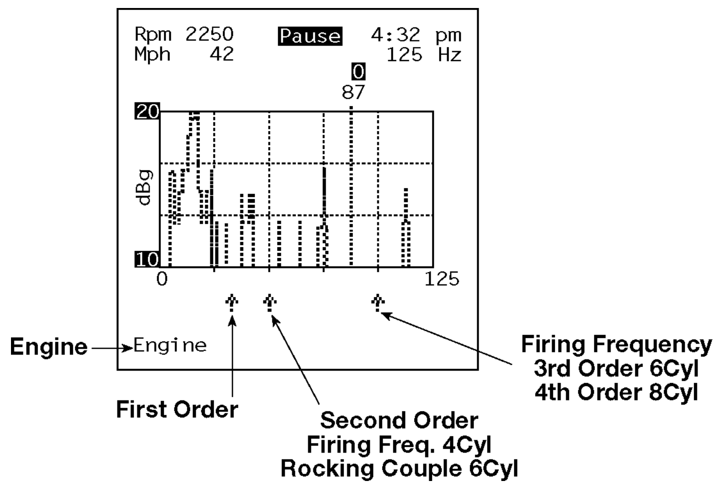


Order
Continued

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 Vibrations

Fig. 1-34



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)

Order
Continued

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.

Firing Frequency

Fig. 1-35

FIRST ORDER ENGINE		FIRING FREQUENCY		
RPM	Hz	4CYL 2nd Order	6CYL 3rd Order	8CYL 4th Order
500	8.3	16.6	24.9	33.2
750	12.5	25	37.5	50
1000	16.6	33.3	49.8	66.4
1500	25	50	75	100
2000	33.3	66.6	99.9	133.2
2500	41.6	83.2	124.8	166.4
3000	50	100	150	200
3500	58.3	110.6	174.9	233.2
4000	66.6	132.4	199.8	266.4

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

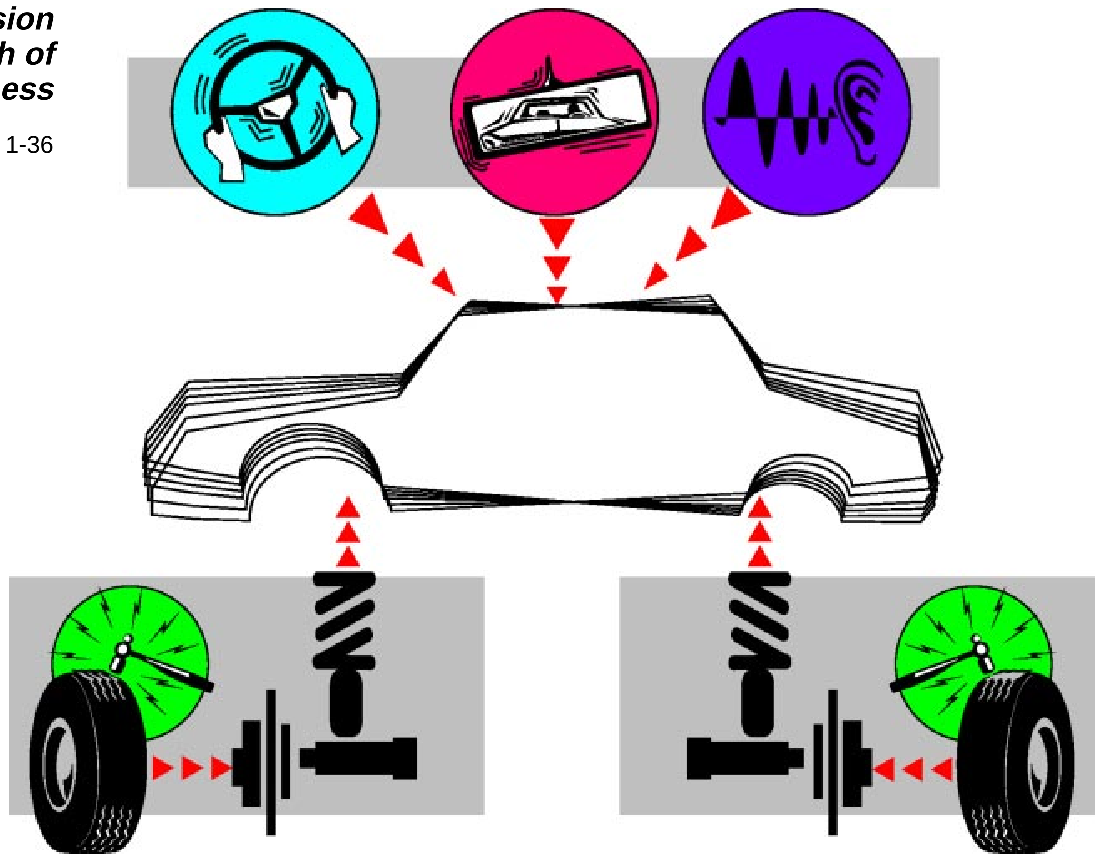
Harshness is the condition a customer senses when a vehicle contacts a **single impact** such as road irregularities, railroad tracks or speed bumps.

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**.

Transmission Path of Harshness

Fig. 1-36



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.

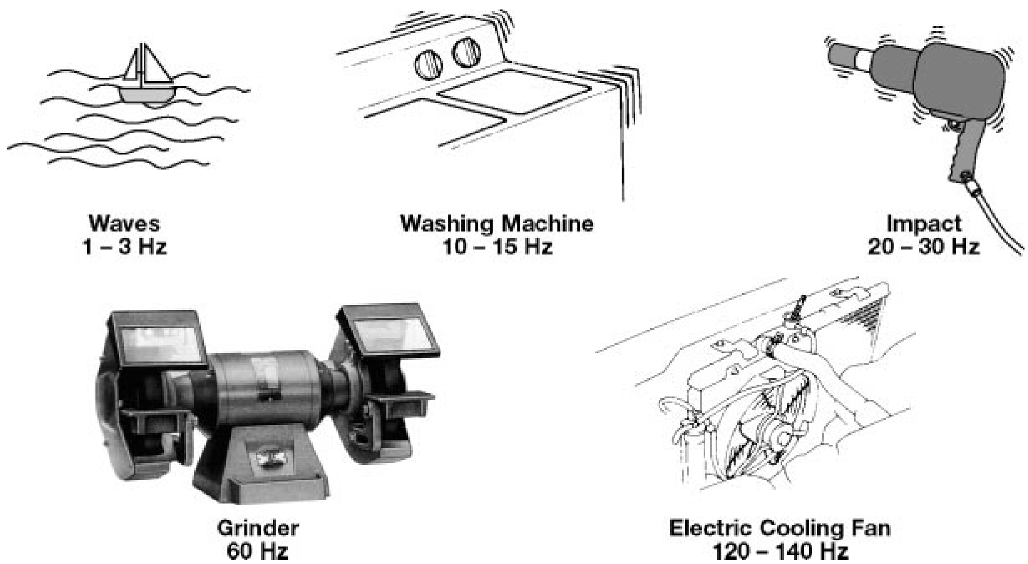
If a symptom feels like one of the examples in fig. **1-38** then the **frequency is the same** as noted. This frequency or speed can now be associated with a component group and pinpoint diagnosis can be conducted in that component area.

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 10-15 Hz depending on the tire/wheel diameter.

Example Vibrations

Fig. 1-38



Common NVH Symptoms

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

Notes

SYMPTOM	SENSATION	CONDITIONS
Body Shake	1. A major vertical and/or lateral vibration of the body, seats and steering wheel. 2. Frequency 10-30 Hz	1. The vibration occurs at a specific speed when driving at a moderate or high speed.
Steering Flutter and Shimmy	1. Rotational steering wheel vibration 2. Shimmy has a relatively low frequency 5-15 Hz 3. Flutter is a higher frequency than shimmy	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.
Accelerator pedal vibration	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)	1. The vibration occurs at a high engine RPM 2. Vehicle speed has no impact on the vibration.
Shift lever vibration	1. A vibration of a small amplitude felt at the shift lever. 2. Frequency 100-200 Hz	1. The vibration occurs at a specific RPM at high engine speed.
Riding comfort	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	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.
Harshness	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	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.
Road noise	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	1. It changes with the surface of the road. The rougher the road, the more noise.

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 100-5k Hz	1. Occurs on pavement with tires having blocked or lug pattern tread. 2. The noise is more noticeable on flat, well paved roads.

CAUSES	VIBRATING SYSTEM	REMARKS
Vibrating forces 1. Tire runout, imbalance or a uniformity problem 2. Rotor or Drum Imbalance 3. Axle hub eccentricity, runout or imbalance Resonators 1. Suspension 2. Engine 3. Body 4. Seat 5. Steering Linkage	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.
Vibrating force Flutter 1. Tire runout, imbalance and uniformity condition 2. Rotor imbalance 3. Axle hub eccentricity, runout or imbalance Shimmy 1. Kick-back from a rough road 2. Tire deformation 3. Radical vertical movement during braking Resonators 1. Tires - worn or low air pressure 2. Steering linkage - loose, worn components 3. Suspension - misalignment, lack of shock absorber dampening	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 vibrates along the rotationally as a result. Shimmy 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. 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.
Vibrating force 1. Engine Vibration Resonators 1. Throttle linkage 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 1. Engine torque fluctuation 2. Imbalance of revolving or reciprocating engine components Resonators 1. Engine and transmission 2. Driveline 3. Shift lever	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. FF models 1. An engine imbalance causes a vibration in the shift lever.	
Vibrating forces 1. Road irregularities Resonators 1. Tires - air pressure 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.	
Vibrating force 1. Pavement joints, gaps, rail road tracks and speed bumps Resonators 1. Tire characteristics 2. Suspension 3. Body	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.	
Vibrating force 1. Small road surface irregularities Resonators 1. Tires 2. Suspension system 3. Body	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.

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.

SYMPTOM	SENSATION	CONDITIONS
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 200-2k Hz	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.

CAUSES	VIBRATING SYSTEM	REMARKS
Vibrating force 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 2. Torque fluctuation due to propeller shaft joint angle twice per revolution, 2nd order/secondary driveline component 3. Propeller shaft imbalance once per revolution, 1st order/primary driveline component 4. Clutch assembly imbalance 5. Exhaust noise 6. Intake noise 7. Tire uniformity condition Resonators 1. Twisting of the driveline 2. Bending of the driveline 3. Exhaust pipe 4. Rear suspension system 5. Outer body panels	Due to propeller shaft joint angles 1. A propeller shaft joint accelerates and decelerates twice per revolution and generates a torque fluctuation twice per revolution. The vibration is greater the greater the angle. 2. The torque fluctuation starts to vibrate the driveline at a specific speed. The vibration is transmitted via the rear suspension arm bushings and springs to the body panels which generate the booming noise. Due to propeller shaft imbalance 1. An unbalanced propeller shaft generates a vibration once per revolution. 2. The vibrating force bends the driveline and the vibration is transmitted via the rear engine mount, center bearing, rear suspension bushings, to the body panels which generate the booming noise. Due to the transmission of exhaust noise 1. Exhaust noise can be transmitted to the body panels through the floor with direct contact or through the vibration of the air.	1. The body booming noise can be engine related or vehicle speed related 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. 3. Knowing the frequency and order is very helpful in diagnosing which component is generating the vibration.
1. Two vibrations are required and could be a combination of the following: Engine imbalance - 1st order Torque fluctuation - 2nd order 4cyl, 3rd order 6cyl Torque converter imbalance Propeller shaft imbalance - 1st order driveline Flange runout - 2nd order driveline Joint condition or angle - 2nd order driveline Tire vibration Cooling fan imbalance Alternator vibration A/C compressor vibration Power steering pump vibration	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. 2. The vibrations are transmitted to the body through the engine mounts from the torque converter and the rear suspension from the propeller shaft. 3. Correcting the propeller shaft may be the easiest repair. 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. 5. Engine vibrations and accessory vibration can match to cause a beating noise. Removal of belts will help identify the accessory causing the vibration. 6. Depending on differential gear ratio tire vibration and propeller shaft or engine vibrations can cause a beating noise. 7. Two imbalanced tires with a different radius can cause a beating noise.	1. Beating noise due to torque converter slippage can be identified by checking it during lock-up or fluctuating the accelerator pedal. 2. A constant speed is necessary to allow the beating noise to cycle. 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.
Vibrating force 1. Mechanical noise - valve train, timing chain, piston, connecting rod, crankshaft, accessories 2. Combustion noise 3. Fan noise 4. Intake air noise 5. Exhaust noise Resonators 1. Engine 2. Accelerator cable 3. Body panels	1. The sound is transmitted through the air or through the body via engine or exhaust mounts.	1. Engine noise can be improved by reducing the noise from the source or insulting against the noise. 2. The following are examples: Holes plugged with grommets Asphalt sheets Sealer Sandwich steel sheets with insulators inside Pad for engine hood Specially designed engine mounts

Vibrating force 1. Swirls of air generated by protrusions and steps in the body surface. 2. Leakage of air through gaps in the body.	1. Wind noise is generated when air hits or is swirled by an object. The sound enters through a door or window. 2. 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.	1. Refer to the Interior Noise and Wind Noise programs for detailed procedures on repairs.

SYMPTOM	SENSATION	CONDITIONS
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. 3. Frequency 5-20 Hz.	1. Occurs when brake is applied lightly or heavily.

CAUSES	VIBRATING SYSTEM	REMARKS
Vibrating force 1. Gear meshing error - nicked, worn or damaged tooth, incorrect teeth contact, gear runout and backlash, gear supporting rigidity Resonators 1. Gear vibration 2. Transmission case 3. Engine supports and mounts 4. Propeller shaft 5. Rear suspension 6. Body panels	FR 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. FF 1. Sound is transmitted from the transaxle case to the body via the engine mounting and shifter.	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.
Vibrating force 1. Same as transmission gear whine Resonators 1. Same as transmission gear whine	FR 1. Inaccurate meshing of the differential gears causes the gears to vibrate. 2. The vibration is transmitted to the differential carrier and amplified by the resonance of the propeller shaft and the rear suspension. It is then transmitted to the body. FF 1. The noise is transmitted directly to the passenger compartment via the case, mounts, cables, and the air.	
Vibrating force 1. Friction characteristics of the facing material and runout of the clutch disc 2. Unequal height of the diaphragm spring fingers 3. Binding of the clutch cable or linkage Resonators 1. Driveline	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.	1. Foreign material such as oil or grease will contribute to the condition.
Vibrating force 1. Torque fluctuation of the engine Resonators 1. Engine mounts 2. Body 3. Steering wheel	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.	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.
Vibrating force 1. Torque fluctuation during starting of the engine Resonators 1. Engine mounts 2. Body	1. Engine rolls due to the fluctuation in compression. 2. This movement acts on the mounts causing the body to shake.	1. A heavy hitting noise could be associated with this condition if components such as the exhaust contact the body.
Vibrating force 1. Torque fluctuation of the engine Resonators 1. Engine mount 2. Exhaust pipe and supports 3. Body	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.	1. Transverse mounted engines are more prone to this type of vibration and have specially designed mounts and exhaust systems
Vibrating force 1. Rust or runout, in the rotor or drum 2. Runout of the rear axle flange 3. Runout of the rotor and rim mating surface Resonators 1. Pad 2. Brake pedal 3. Steering knuckle, axle hub or shaft 4. Suspension 5. Body	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.	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.

Vibrating force 1. Fluctuation and friction of the pads Resonators 1. Pads or shoes 2. Rotor 3. Drum and backing plate	1. The friction surface between the brake components causes a vibration which resonates with the rotor, drum or backing plate.	1. It is important that the anti-squeal components are in place during installation.

Notes

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:

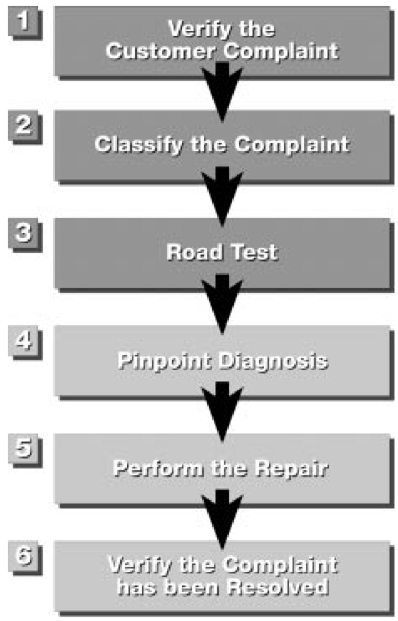
- Verify the complaint
- Classify the complaint
- Road test with NVH analyzer

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.

Section 2

NVH DIAGNOSTIC PROCEDURES



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.

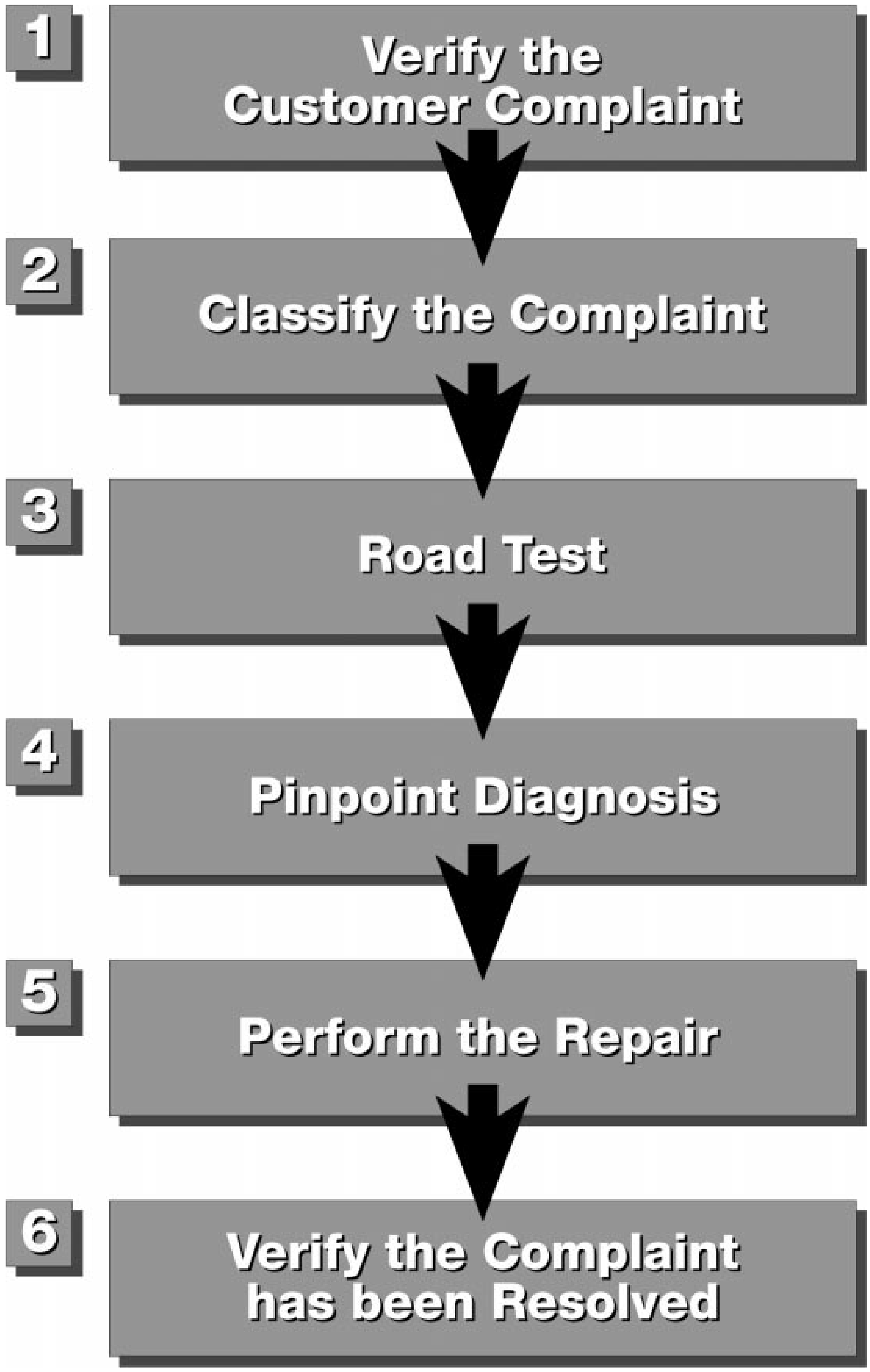

1
Verify the
Customer Complaint
2
Classify the Complaint
3
Road Test
4
Pinpoint Diagnosis
5
Perform the Repair
6
Verify the Complaint
has been Resolved

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.

Repair Order for 4Runner

Fig. 2-2

TOYOTA MOTOR SALES U.S.A.
VEHICLE SERVICE CENTER
19001 S. WESTERN AVENUE
TORRANCE, CALIFORNIA 90509

SERVICE WORK ORDER

PAGE 1 OF 1 ANYBODY , JOHN   DATE 7/26/93   TIME 14:35   RO# 1018938

*** SERVICE HISTORY ***

???	DATE	MILES	PRIME ITEM	MENU ITEMS
???	04/28/93	022549		

MENU/OP   INSTRUCTIONS/NOTES   CONDITION 01 - CUSTOMER PAY

PRIME ITEM   VIBRATIONS AND NOISE BETWEEN
40-60MPH FROM STEERING WHEEL
AND SEAT
-
NOISE COMES FROM REAR
-
CUST STATES IT NEEDS ALIGNMENT

QTS.OIL
LBS.GREASE
GAL. GAS
QTS. TRANS.
ESTIMATE $
ADDITIONAL $
TOTAL $

SERVICE ADV. 500
SAVE PARTS (Y)
PHONE READY (Y)
PROM. TIME PM ☐
DATE 7/26/93
AUTH. TIME PM ☐
DATE
OK'D

SA: 5110 8952000- ALL LEASE VEH

VIN J T 3 V N 3 9 W 9 P 0 0 9 5 2 1 9
YEAR 93 MAKE TOYOTA COLOR DARK GREEN MODEL 4 RUNNER
MILES LICENSE PROD. DOFU
NAME JOHN ANYBODY
ADDRESS 19001 S WESTERN AVENUE
CITY TORRANCE STATE CA ZIP CODE 90009
HOME PHONE (310) 555-1111 BUS PHONE (310) 777-2222 EXT. 357

TERMS
☐ CASH
☐ CREDIT CARD
☐ CHARGE

DISCLAIMER OF WARRANTIES

I hereby authorize the repair hereinafter set forth to be done along with the necessary material and agree that you are not responsible for loss or damage to vehicle or articles left in vehicle in case of fire, theft or any other cause beyond your control or for any delays caused by unavailability of parts or delays in parts shipments by the supplier or transporter. I hereby grant you and/or your employees permission to operate the vehicle herein described on streets, highways or elsewhere for the purpose of testing and/or inspection. An express mechanic's lien is hereby acknowledged on above vehicle to secure the amount of repairs thereto.

NOTICE TO CONSUMER: PLEASE READ IMPORTANT INFORMATION ON REVERSE SIDE

CUSTOMER SIGNATURE X

Case Study: Background
Continued

*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.*

Verify the Customer Complaint

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.

Notes

Customer Interview Sheet

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.

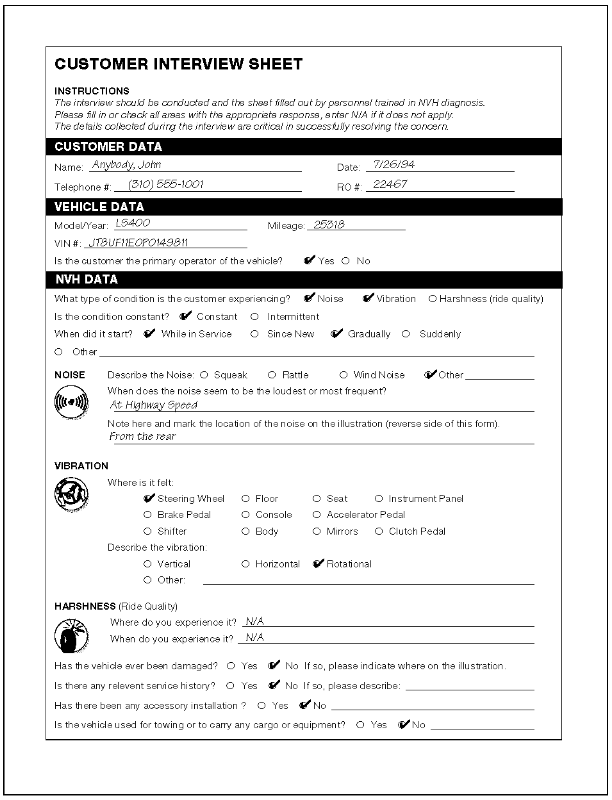
Customer Interview Sheet
Continued

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
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* Date: *7/26/94*
Telephone #: *(310) 555-1001* RO #: *22467*

VEHICLE DATA

Model/Year: *LS400* Mileage: *25318*
VIN #: *JT8UF11E0P0149811*
Is the customer the primary operator of the vehicle? ✔ Yes O No

NVH DATA

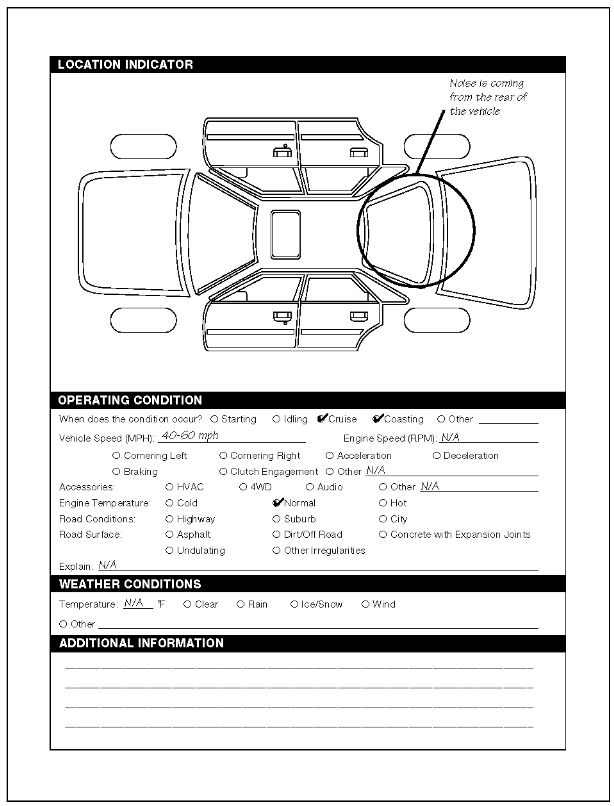
What type of condition is the customer experiencing? ✔ Noise ✔ Vibration O Harshness (ride quality)
Is the condition constant? ✔ Constant O Intermittent
When did it start? ✔ While in Service O Since New ✔ Gradually O Suddenly
O Other

NOISE
Describe the Noise: O Squeak O Rattle O Wind Noise ✔ Other
When does the noise seem to be the loudest or most frequent?
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 O Floor O Seat O Instrument Panel
O Brake Pedal O Console O Accelerator Pedal
O Shifter O Body O Mirrors O Clutch Pedal
Describe the vibration:
O Vertical O Horizontal ✔ Rotational
O Other:

HARSHNESS (Ride Quality)
Where do you experience it? *N/A*
When do you experience it? *N/A*

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



LOCATION INDICATOR

Noise is coming from the rear of the vehicle

OPERATING CONDITION

When does the condition occur? O Starting O Idling ✔ Cruise ✔ Coasting O Other
Vehicle Speed (MPH): *40-60 mph* Engine Speed (RPM): *N/A*
O Cornering Left O Cornering Right O Acceleration O Deceleration
O Braking O Clutch Engagement O Other *N/A*
Accessories: O HVAC O 4WD O Audio O Other *N/A*
Engine Temperature: O Cold ✔ Normal O Hot
Road Conditions: O Highway O Suburb O City
Road Surface: O Asphalt O Dirt/Off Road O Concrete with Expansion Joints
O Undulating O Other Irregularities
Explain: *N/A*

WEATHER CONDITIONS

Temperature: *N/A* °F O Clear O Rain O Ice/Snow O Wind
O Other

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 and Vehicle Data

Fig. 2-4

CUSTOMER INTERVIEW SHEET TOYOTA

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   Date: 7/26/94
Telephone #: (310) 555-1001   RO #: 22467

VEHICLE DATA

Model/Year: LS400   Mileage: 25318
VIN #: JT8UF11E0P0149811
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.

Customer Interview Sheet

Continued

The customer is provided with a list of possible locations with a few details specific to each location.

For example:

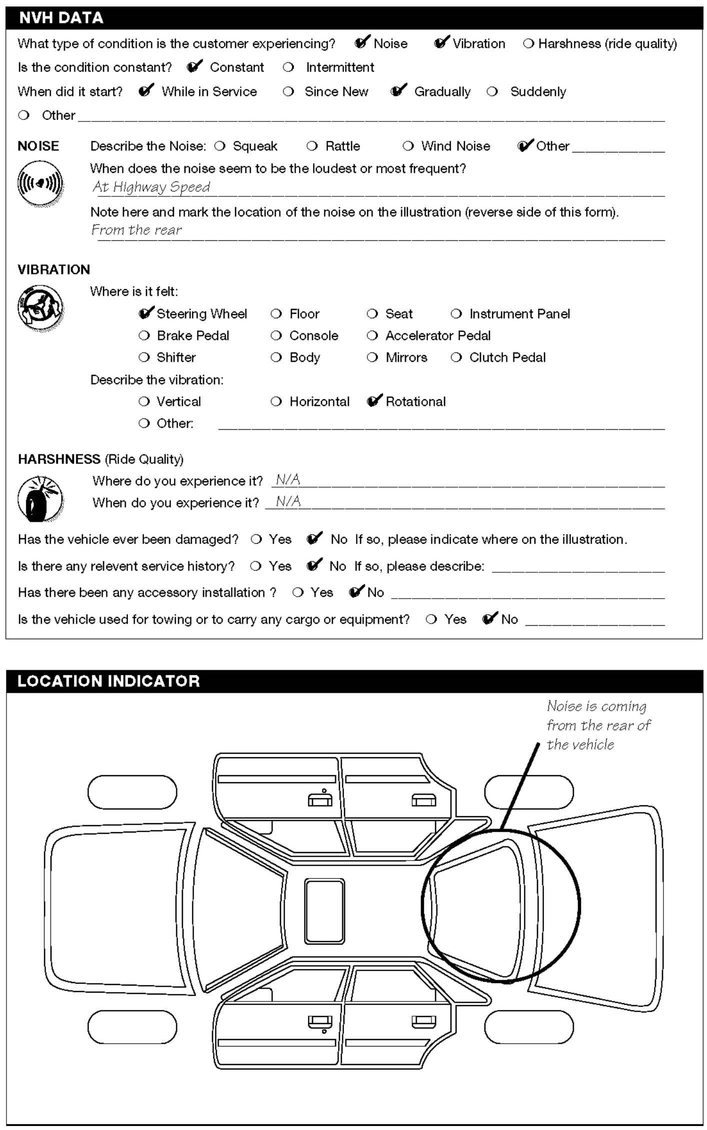
If the steering wheel is the location then there are three possible types of steering wheel vibrations:

- 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

Fig. 2-5



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?

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

❍ 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? *N/A*

When do you experience it? *N/A*

Has the vehicle ever been damaged? ❍ Yes ✔ No If so, please indicate where on the illustration.

Is there any relevent 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 ______

Customer Interview Sheet
Continued

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 over look it.

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

Vehicle and Operating Conditions

Fig. 2-6

OPERATING CONDITION

When does the condition occur? ❍ Starting ❍ Idling ✔Cruise ✔Coasting ❍ Other ________

Vehicle Speed (MPH): 40-60 mph Engine Speed (RPM): N/A

❍ Cornering Left ❍ Cornering Right ❍ Acceleration ❍ Deceleration

❍ Braking ❍ Clutch Engagement ❍ Other N/A

Accessories: ❍ HVAC ❍ 4WD ❍ Audio ❍ Other N/A

Engine Temperature: ❍ Cold ✔Normal ❍ Hot

Road Conditions: ❍ Highway ❍ Suburb ❍ City

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

❍ Undulating ❍ Other Irregularities

Explain: N/A

WEATHER CONDITIONS

Temperature: N/A °F ❍ Clear ❍ Rain ❍ Ice/Snow ❍ Wind

❍ Other ________

ADDITIONAL INFORMATION

____

____

____

____

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*
- *Vehicle condition section*
- *Road condition section*
- *Engine RPM*
- *Weather 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.*

Notes

WORKSHEET #1
Verification of the Customer complaint

Vehicle	Year/Prod. Date	Engine	Transmission

Diagnostic Description: **Verify the Complaint**

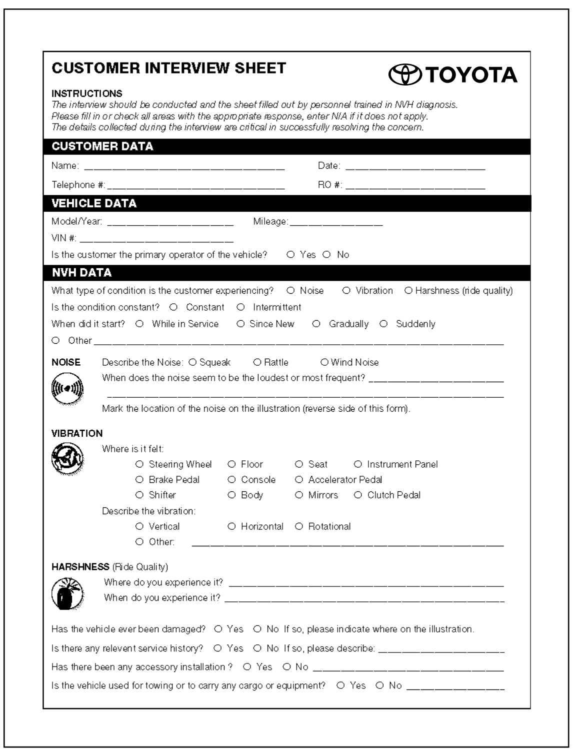
It is critical for the technician to **experience** the complaint for it to be successfully resolved. The Customer Interview Sheet is a **tool**, used by trained NVH service personnel, to collect the details associated with the customer complaint. With the information from the interview the technician 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).

Customer Interview Sheet

Fig. 2-7



CUSTOMER INTERVIEW SHEET TOYOTA

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: ____ Date: ____
Telephone #: ____ RO #: ____

VEHICLE DATA
Model/Year: ____ Mileage: ____
VIN #: ____
Is the customer the primary operator of the vehicle? O Yes O No

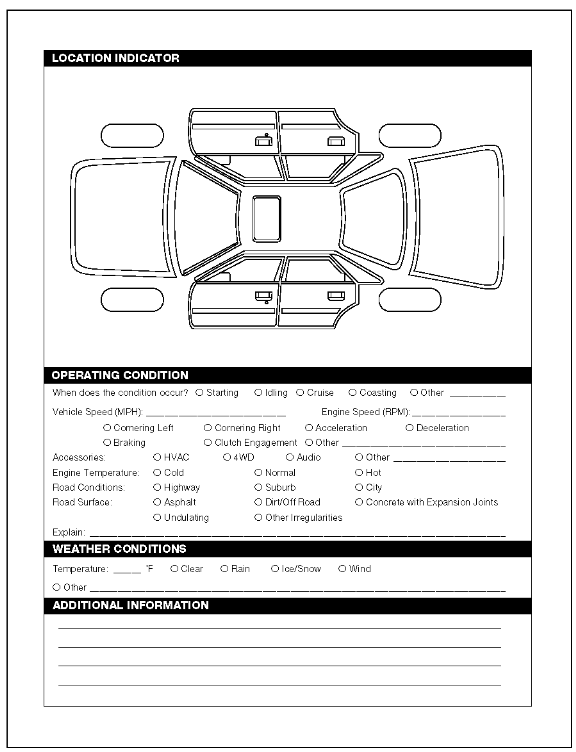
NVH DATA
What type of condition is the customer experiencing? O Noise O Vibration O Harshness (ride quality)
Is the condition constant? O Constant O Intermittent
When did it start? O While in Service O Since New O Gradually O Suddenly
O Other ____

NOISE Describe the Noise: O Squeak O Rattle O 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:
O Steering Wheel O Floor O Seat O Instrument Panel
O Brake Pedal O Console O Accelerator Pedal
O Shifter O Body O Mirrors O Clutch Pedal
Describe the vibration:
O Vertical O Horizontal O Rotational
O Other: ____

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

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



LOCATION INDICATOR

OPERATING CONDITION
When does the condition occur? O Starting O Idling O Cruise O Coasting O Other ____
Vehicle Speed (MPH): ____ Engine Speed (RPM): ____
O Cornering Left O Cornering Right O Acceleration O Deceleration
O Braking O Clutch Engagement O Other ____
Accessories: O HVAC O 4WD O Audio O Other ____
Engine Temperature: O Cold O Normal O Hot
Road Conditions: O Highway O Suburb O City
Road Surface: O Asphalt O Dirt/Off Road O Concrete with Expansion Joints
O Undulating O Other Irregularities
Explain: ____

WEATHER CONDITIONS
Temperature: ____ °F O Clear O Rain O Ice/Snow O Wind
O Other ____

ADDITIONAL INFORMATION

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.

   NOTE

   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?

Notes

CUSTOMER INTERVIEW SHEET

TOYOTA

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

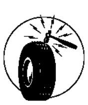
Where is it felt:

❍ 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? ____

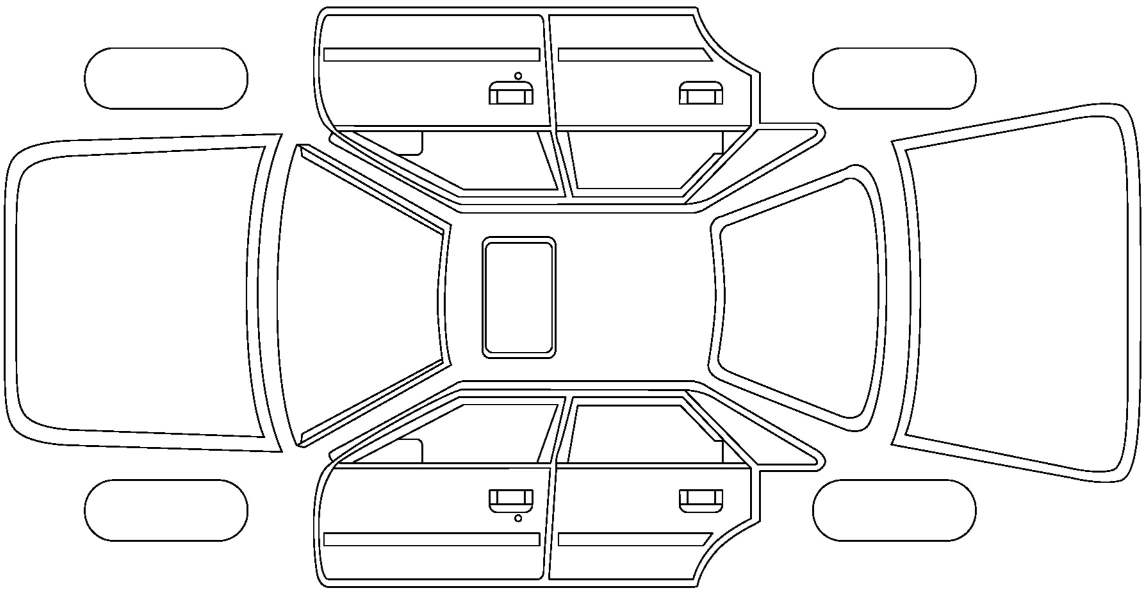
Has the vehicle ever been damaged? ❍ Yes ❍ No If so, please indicate where on the illustration.

Is there any relevent 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

____

____

____

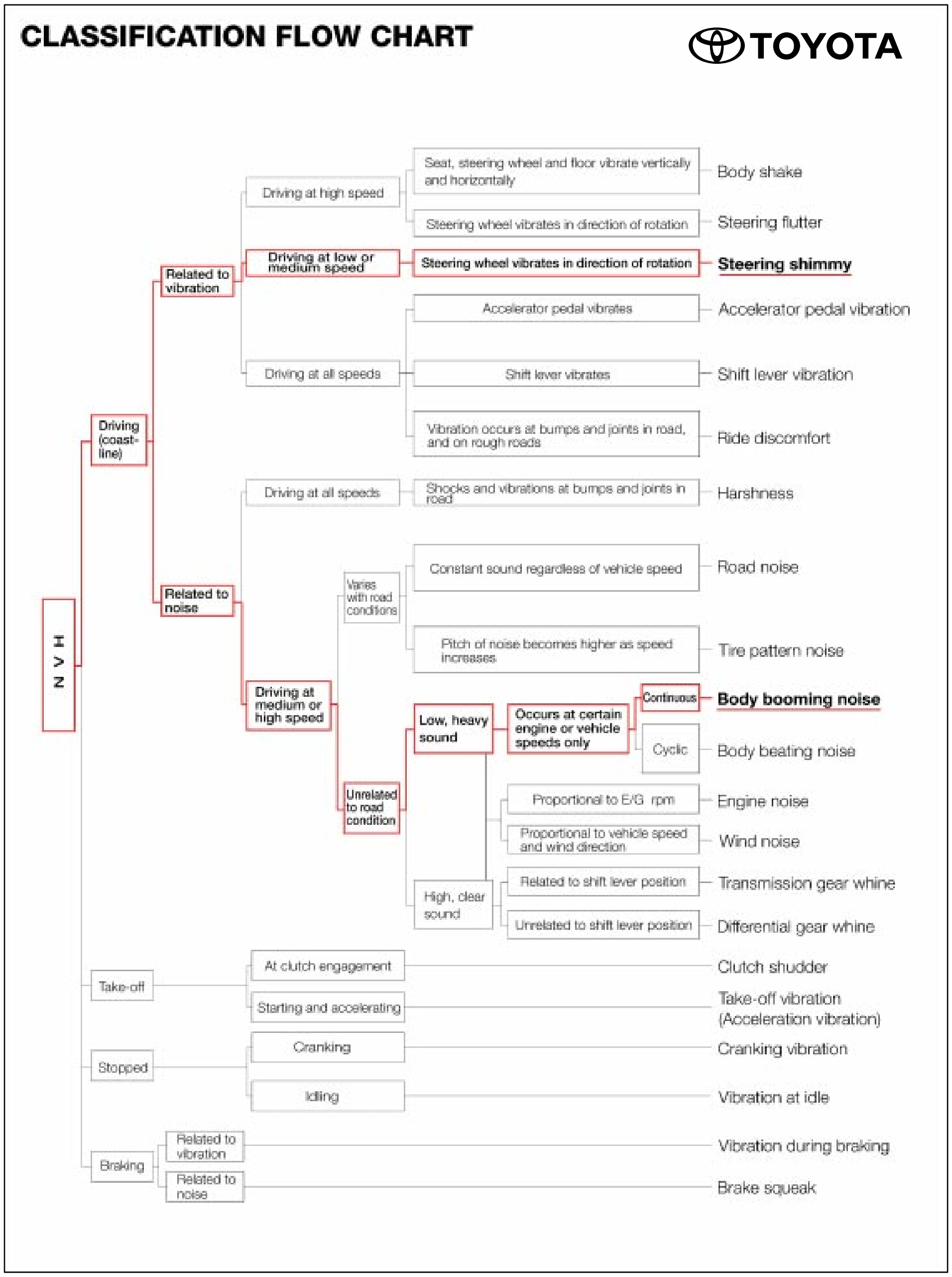
____

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

Fig. 2-8



Classify the Complaint
Continued

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).

WORKSHEET #2
Classify the complaint

Vehicle	Year/Prod. Date	Engine	Transmission

Diagnostic Description: Symptoms Classification Flow Chart

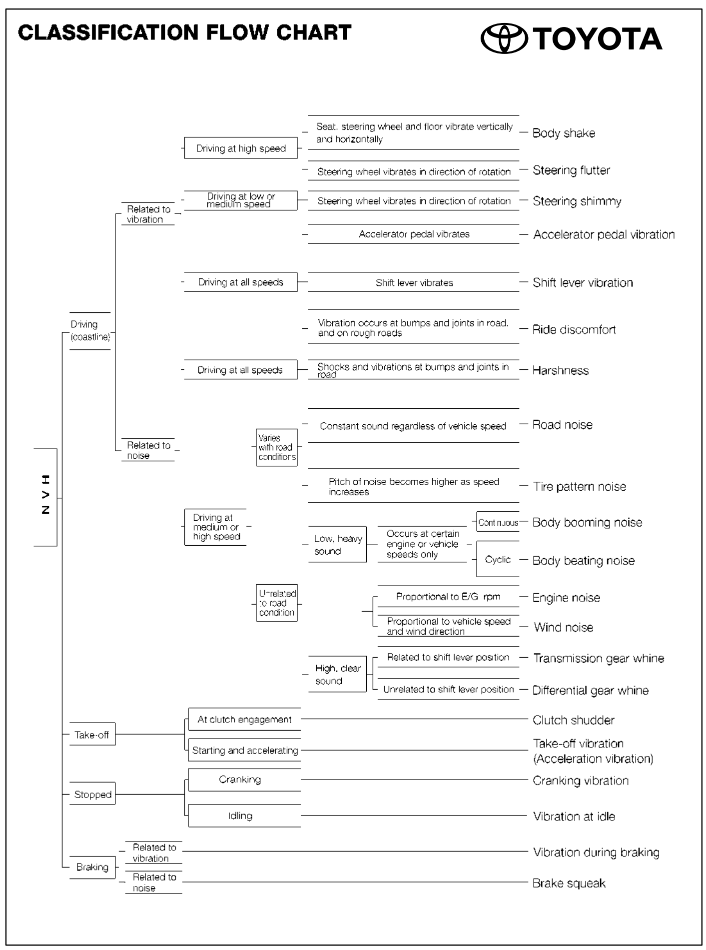
The recent emphasis placed on NVH in automobiles has brought with it a **new vocabulary.** In addition, **quality communication** from the customer to the technician, has been identified as one of the major areas of concern for successful NVH service.

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

Fig. 2-9



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?

    ____

    ____

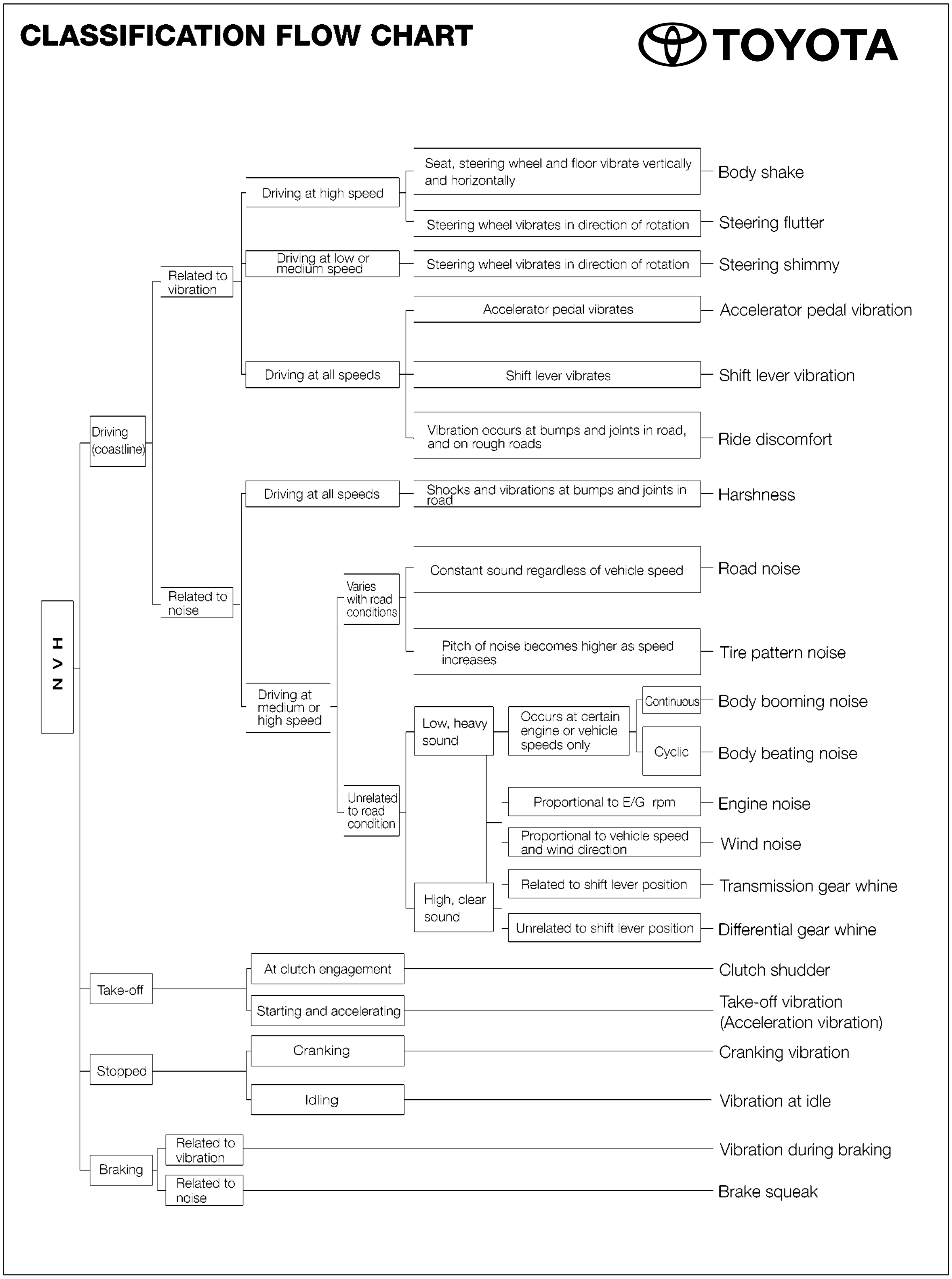
    ____

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.

Notes


CLASSIFICATION FLOW CHART
TOYOTA
N V H
Driving (coastline)
Related to vibration
Driving at high speed
Seat, steering wheel and floor vibrate vertically and horizontally
Body shake
Steering wheel vibrates in direction of rotation
Steering flutter
Driving at low or medium speed
Steering wheel vibrates in direction of rotation
Steering shimmy
Driving at all speeds
Accelerator pedal vibrates
Accelerator pedal vibration
Shift lever vibrates
Shift lever vibration
Vibration occurs at bumps and joints in road, and on rough roads
Ride discomfort
Related to noise
Driving at all speeds
Shocks and vibrations at bumps and joints in road
Harshness
Driving at medium or high speed
Varies with road conditions
Constant sound regardless of vehicle speed
Road noise
Pitch of noise becomes higher as speed increases
Tire pattern noise
Unrelated to road condition
Low, heavy sound
Occurs at certain engine or vehicle speeds only
Continuous
Body booming noise
Cyclic
Body beating noise
Proportional to E/G rpm
Engine noise
Proportional to vehicle speed and wind direction
Wind noise
High, clear sound
Related to shift lever position
Transmission gear whine
Unrelated to shift lever position
Differential gear whine
Take-off
At clutch engagement
Clutch shudder
Starting and accelerating
Take-off vibration (Acceleration vibration)
Stopped
Cranking
Cranking vibration
Idling
Vibration at idle
Braking
Related to vibration
Vibration during braking
Related to noise
Brake squeak

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.

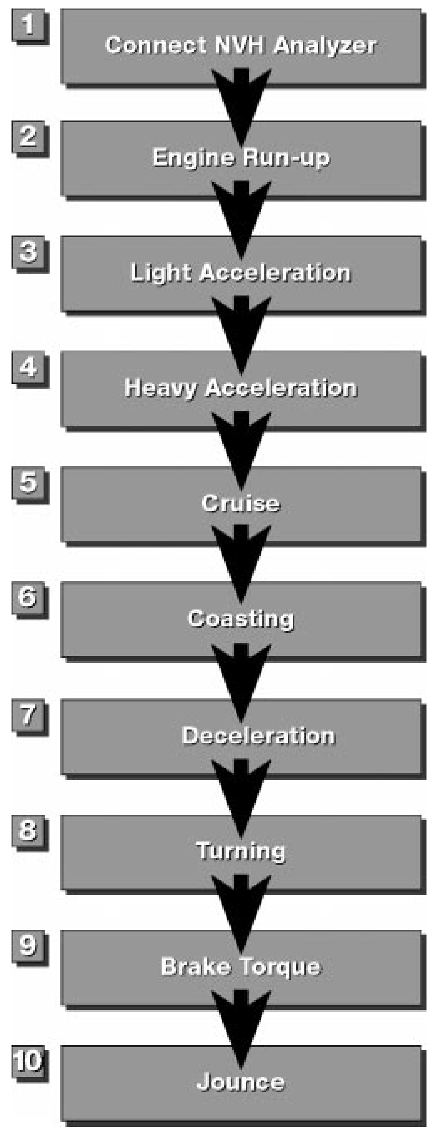
Road Test

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.

Road Test Procedures

Fig. 2-10



Road Test
Continued

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**.

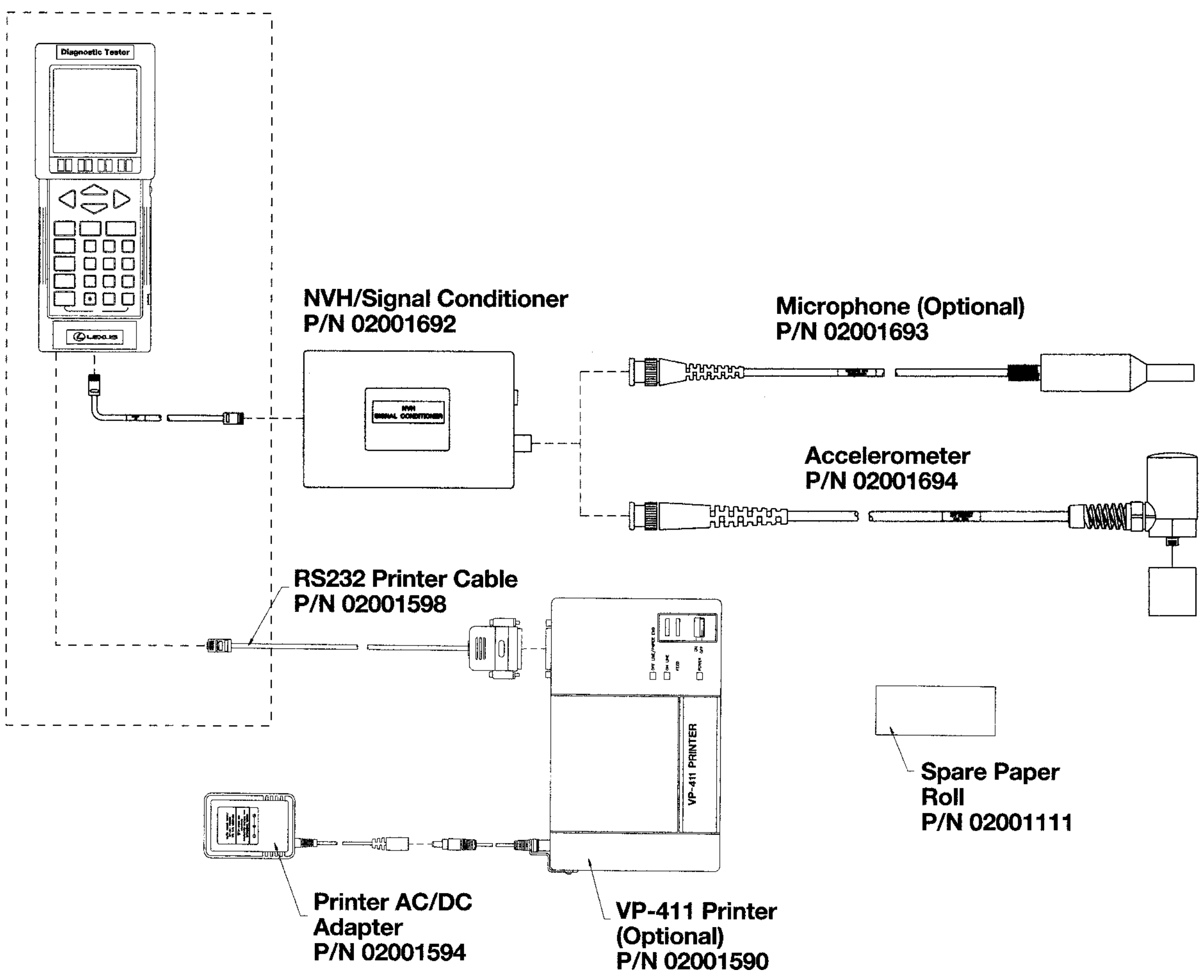
Knowing the **frequency** of the condition will help classify the symptom. The large list of possibilities can be reduced considerably due to the fact that only specific components operate at specific frequencies.

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).

NVH Analyzer

Fig. 2-11



Collecting, Reading and Analyzing NVH Data
Continued

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:

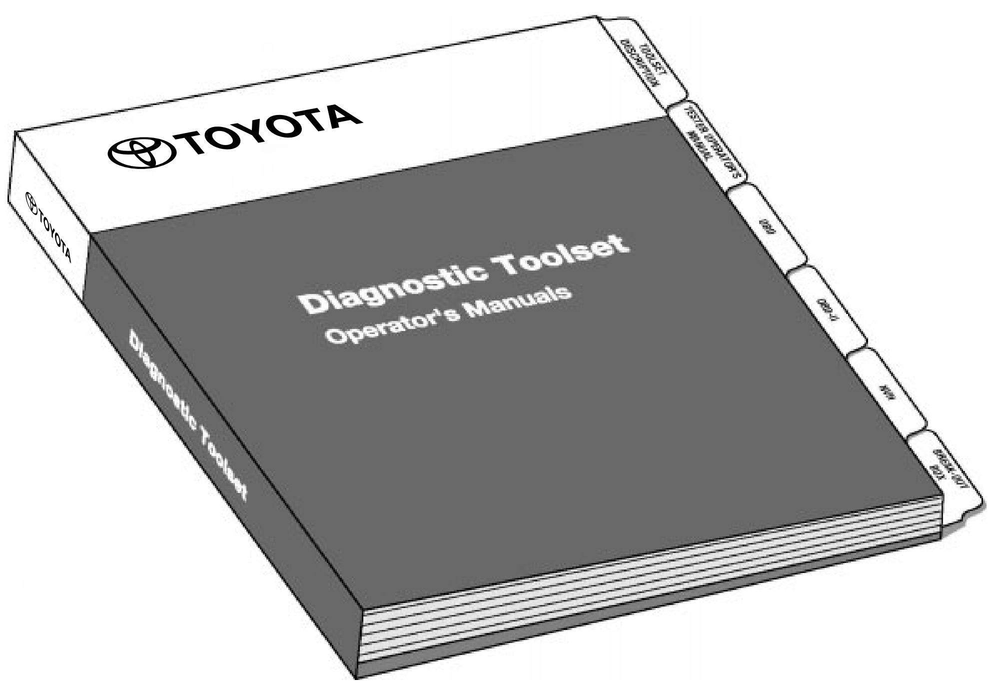
- Hardware
- Features
- Operating precautions
- Getting started
- Using the RS232 and instrumentation ports

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**.

Toyota Diagnostic Tool Set Manual

Fig. 2-11b



WORKSHEET #3A
Getting Started with the NVH Analyzer

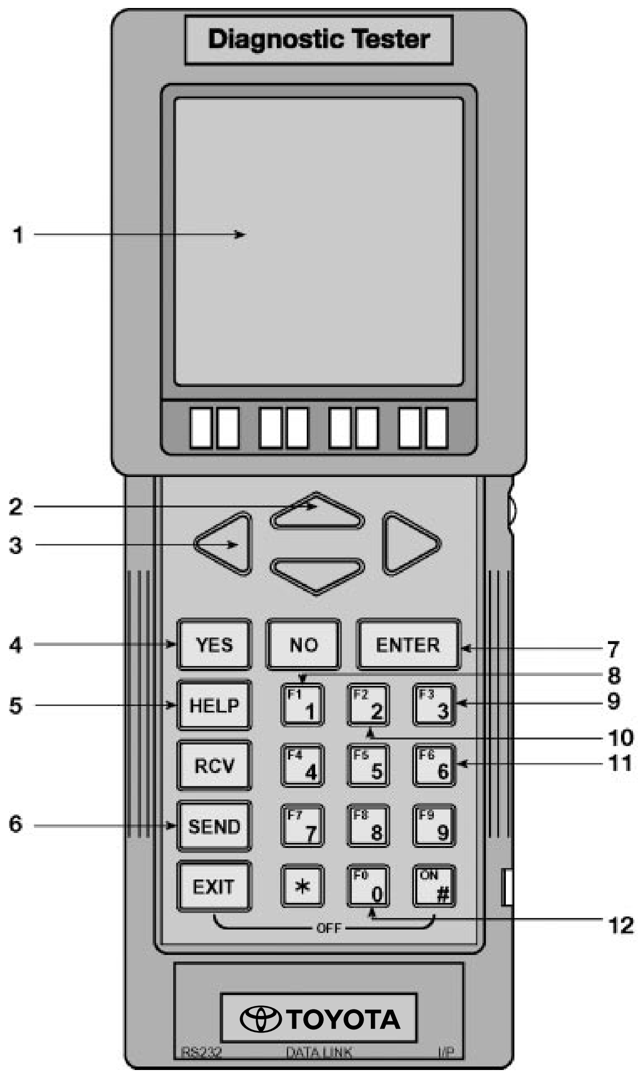
Description: **The NVH Analyzer Set-up**

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. YES key changes the company on the program ID screen
5. HELP displays a summary of active keys
6. SEND with ON # will print the screen
7. ENTER moves forward through the menu
8. F1 1 key changes NVH displays
9. F3 3 key changes the source indicators
10. F2 2 key changes frequency band width
11. F6 6 key saves a paused screen
12. F0 0 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.

   ____

   ____

9. List **three** useful pieces of information available on the vehicles parameters screen. Explain.

   ____

   ____

   ____

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"?

    ____

Notes

WORKSHEET #3B
Getting Started with the NVH Analyzer

Description: **The NVH Analyzer Data Displays**

The NVH software provides **three data displays** for NVH diagnosis.

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

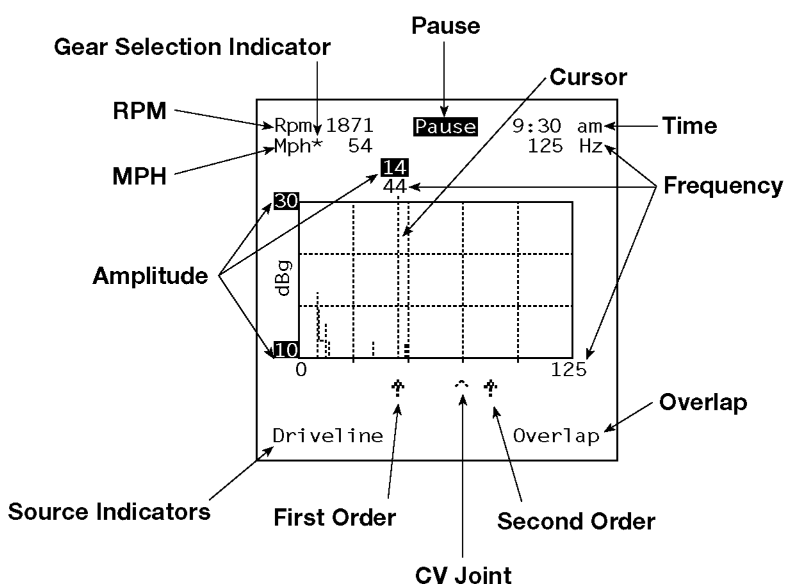
These displays are available to **analyze** the vibrations and noise in a vehicle. They are accessed after the vehicle and function selections are made. (worksheet #3A) In addition to the vehicle vibrations, each display provides information including:

- 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



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 dBs

    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?

WORKSHEET #3C
Getting Started with the NVH Analyzer

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.

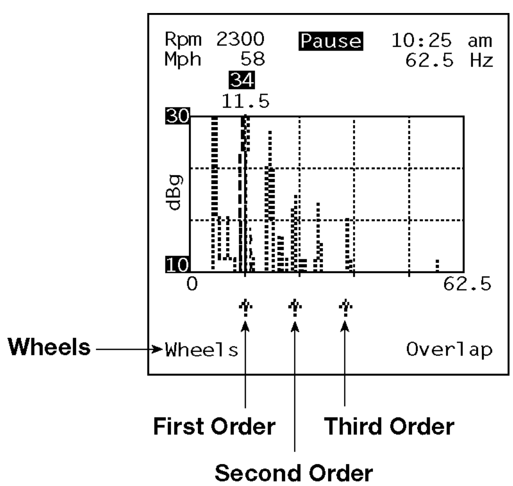
The NVH training simulation software contains pre-recorded vehicles with **typical vibration characteristics** and **customer complaint vibrations**. Specific scenarios are selected by choosing one of the following vehicles on the vehicle select screen.

- 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.

2d Display

Fig. 2-14



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** then 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?

QUESTION / VEHICLE	1. ANTICIPATED VIBRATION SOURCE/ORDER	2. BEST FREQUENCY RANGE	3. "SPIKES" ABOVE 125 Hz YES/NO	4. BEST AMPLITUDE RANGE
LANDCRUISER (30)	/	Hz	Hz YES/NO	dBg
TRUCK A (33)	/	Hz	Hz YES/NO	dBg
TRUCK B (73)	/	Hz	Hz YES/NO	dBg
TRUCK C (76)	/	Hz	Hz YES/NO	dBg
CAMRY A (35)	/	Hz	Hz YES/NO	dBg
CAMRY B (72)	/	Hz	Hz YES/NO	dBg

	SYMPTOM 1
LANDCRUISER (30)	
TRUCK A (33)	
TRUCK B (73)	
TRUCK C (76)	
CAMRY A (35)	
CAMRY B (72)	

5. OVERLAP YES/NO 6. INDICATORS 7. PLAN OF ACTION	8. BARCHART LEVEL	9. ACTUAL VIBRATIONS SOURCE/ORDER	10. CONCLUSIONS PLAN OF ACTION
YES/NO	ENGINE DRIVELINE WHEELS		
YES/NO	ENGINE DRIVELINE WHEELS		
YES/NO	ENGINE DRIVELINE WHEELS		
YES/NO	ENGINE DRIVELINE WHEELS		
YES/NO	ENGINE DRIVELINE WHEELS		
YES/NO	ENGINE DRIVELINE WHEELS		

SYMPTOM 2

2D	BARCHART	3D
LANDCRUISER (30)		
ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE
COMMENTS		
CAMRY A (35)		
ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE
COMMENTS		
CAMRY B (72)		
ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE
COMMENTS		

2D	BARCHART	3D
TRUCK A (33)		
ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE
COMMENTS		
TRUCK B (73)		
ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE
COMMENTS		
TRUCK C (76)		
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COMMENTS		

Notes

WORKSHEET #3D
Dynamic NVH Data Analysis

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.

Notes

2D	BARCHART	3D
BEFORE		
ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE
AFTER		
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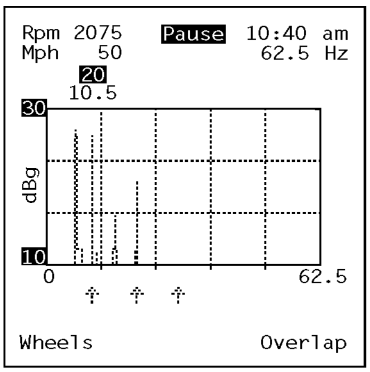
COMMENTS		

Diagnostic Display Interpretation Hints
"VIBRATION" function

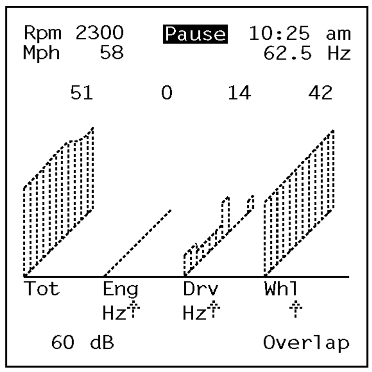
Learning to associate the NVH data with vehicle vibrations takes **practice** and an **understanding** of how the different displays provide information. It is also helpful to understand how the displays can be compared to one another to isolate the data that relates to the complaint.

NVH Analyzer Displays

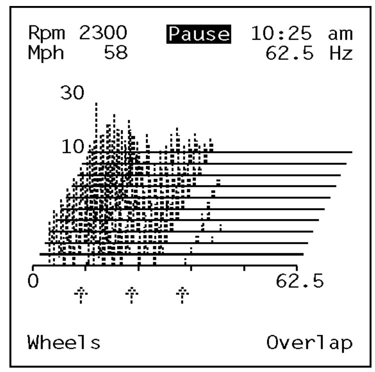
Fig. 2-15



2d



BARCHART



3d

“VIBRATION” function
Continued

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 0] [F6 6]) 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 1]), select the driveline indicators ([F3 3]), 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.

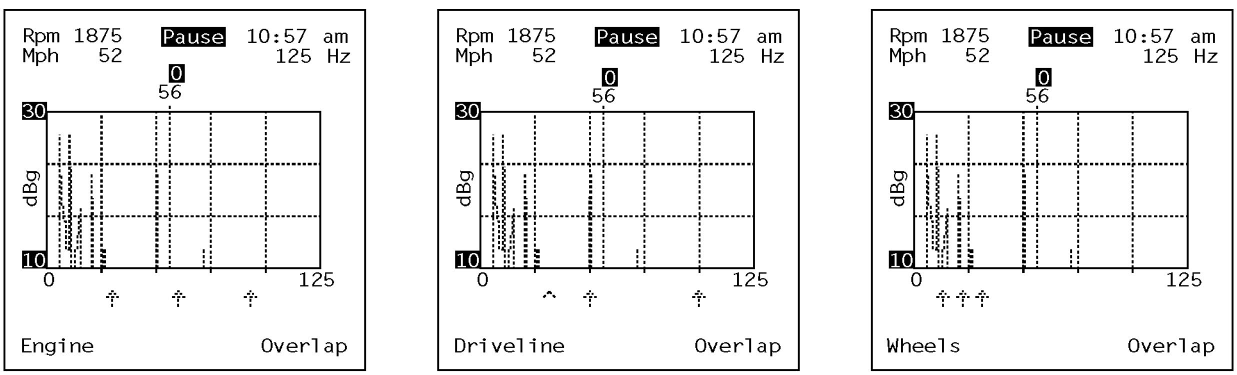
"VIBRATION" function
Continued

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.

2d Display Indicators

Fig. 2-16



ENGINE **DRIVELINE** **WHEELS**

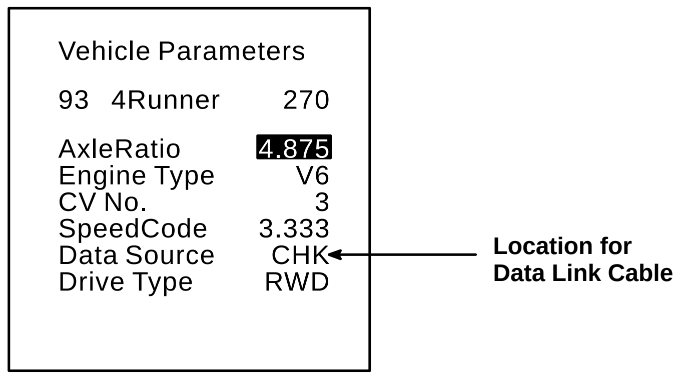
“VIBRATION” function
Continued

NOTE

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.

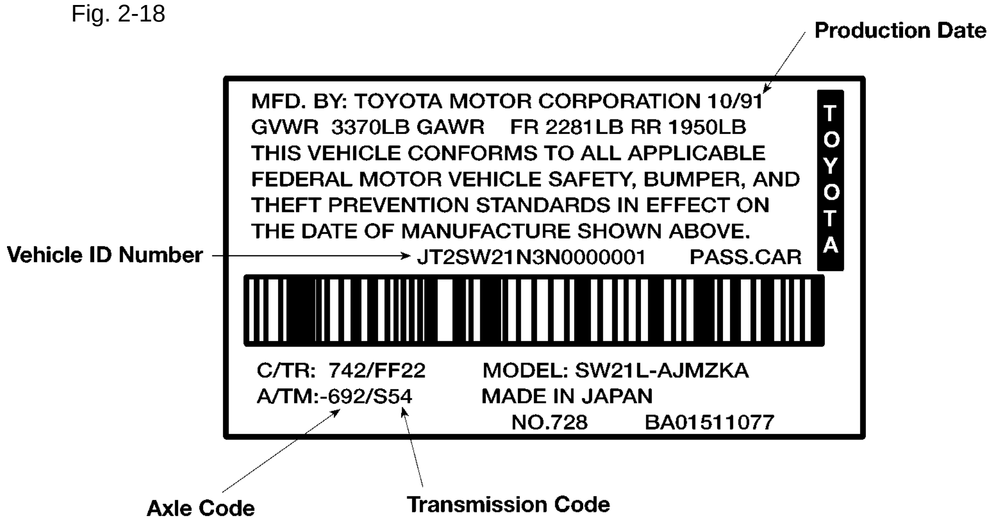
Vehicle Parameters Menu

Fig. 2-17



Sticker on “B” Pillar

Fig. 2-18



“VIBRATION” function
Continued

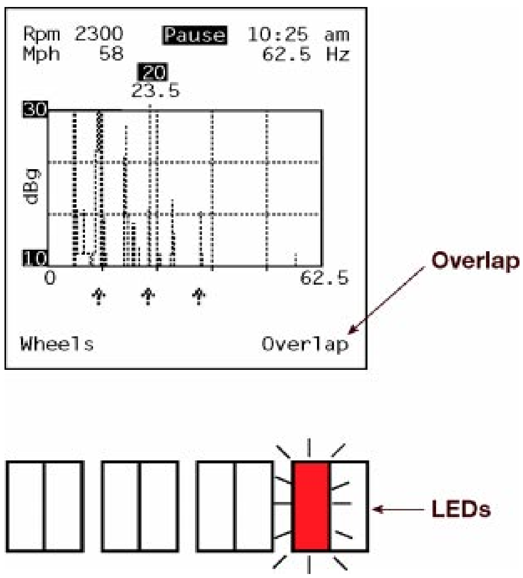
It is possible to have a unique situation that requires research in the Repair Manuals, parts fiche, TSBs and NCFs to collect the specifications necessary to modify the data base.

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 then 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.

Overlap/LEDs Indicators

Fig. 2-19



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 (F3 3) 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.

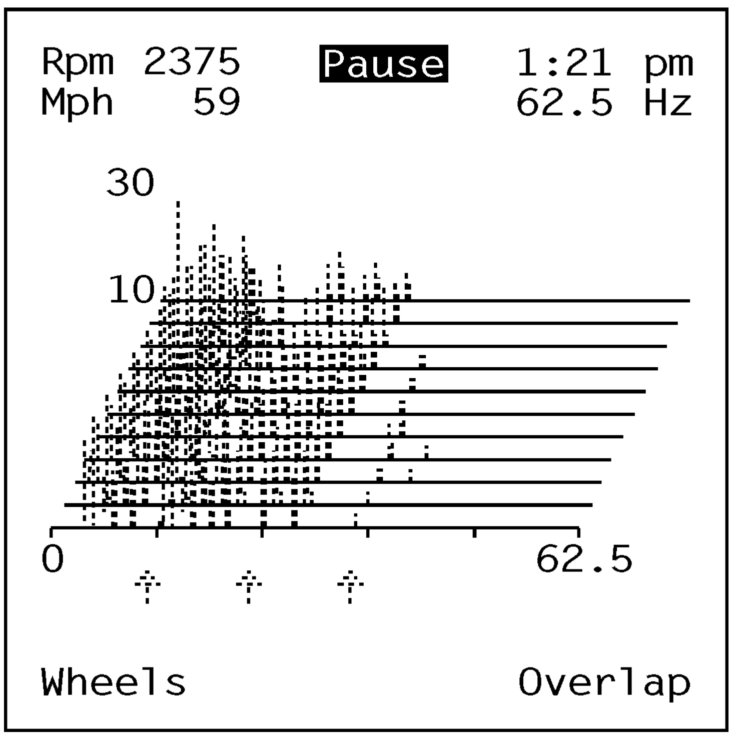
“VIBRATION” function
Continued

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.

3d Display

Fig. 2-20



“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 & ([*] [F2]) backward
- Floor and ceiling level of the amplitude scale (⇕)
- 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.

"VIBRATION" function
Continued

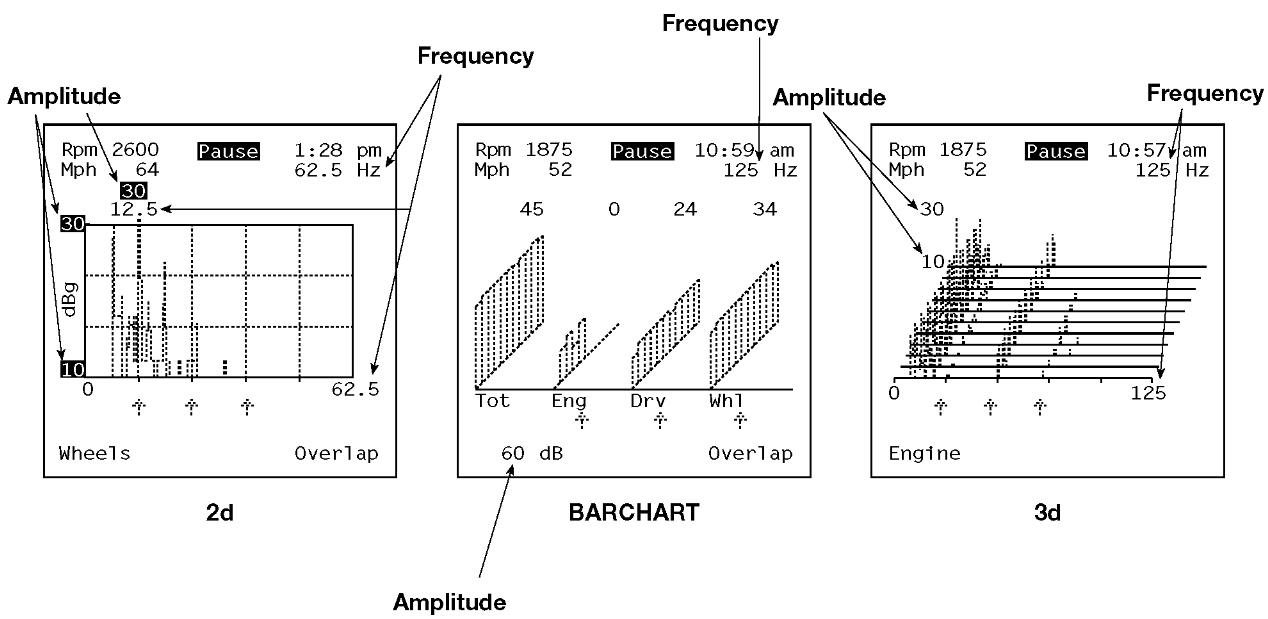
The **floor and ceiling level of the amplitude scale** is adjustable from the **default position of 10 to 30 dBg** range with the ⇕ keys. The following ranges are available:

- 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

Fig. 2-21



“VIBRATION” function
Continued

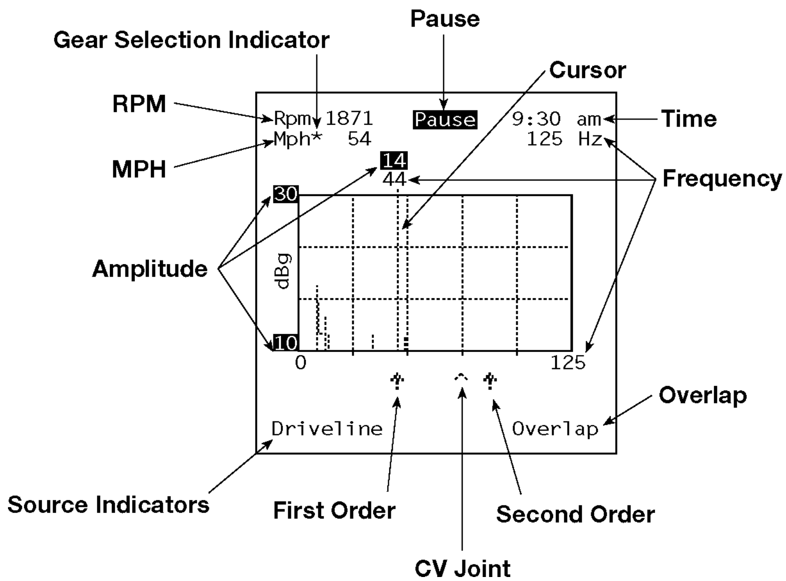
Additional display features include:

- RPM and MPH display
- Time display
- Cursor w/Hz and dBg (◁▷)
- “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.

Screen Indicators

Fig. 2-22



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 vehicles **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** [F8 8] **and select the gear manually** for the driveline and wheel indicators to be accurate.

"VIBRATION" function
Continued

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 (F8 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.

NOTE 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.

NOTE 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.

Scale	Increment
500	4 Hz
250	2 Hz
125	1 Hz
62.5	.5 Hz

"NOISE" function (option)

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 dB**g**
- 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**.

"NOISE" function (option) Continued

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.

Heavy Acceleration Test

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

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:

Item	Description
Vehicles w/o locking torque converters	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 **not** under load and that stable cruise has been established for accurate driveline and wheel arrow indicators.
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**.

NOTE

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.

CAUTION

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.

NOTE

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

WORKSHEET #4A
Road Test

Vehicle	Year/Prod. Date	Engine	Transmission

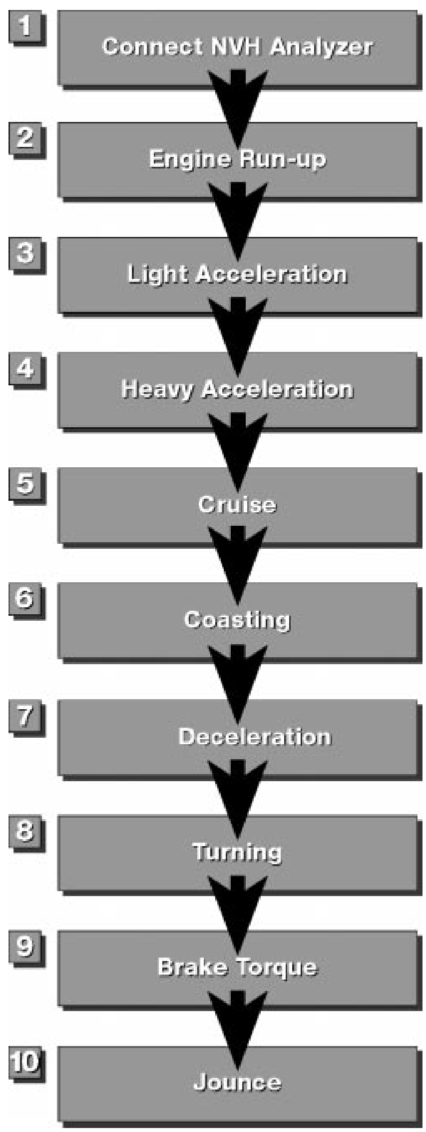
Diagnostic Description: **Road Test with the NVH Analyzer Vibration Function**

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.

Road Test Procedures

Fig. 2-23



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 my 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.

	FIRST ORDER Freq/Ampl	SECOND ORDER Freq/Ampl	THIRD ORDER Freq/Ampl
ENGINE	/	/	/
DRIVELINE	/	/	/
WHEELS	/	/	/

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.

2D	BARCHART	3D
BEFORE		
ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE
AFTER		
ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE
COMMENTS		

WORKSHEET #4B
Road Test

Vehicle	Year/Prod. Date	Engine	Transmission

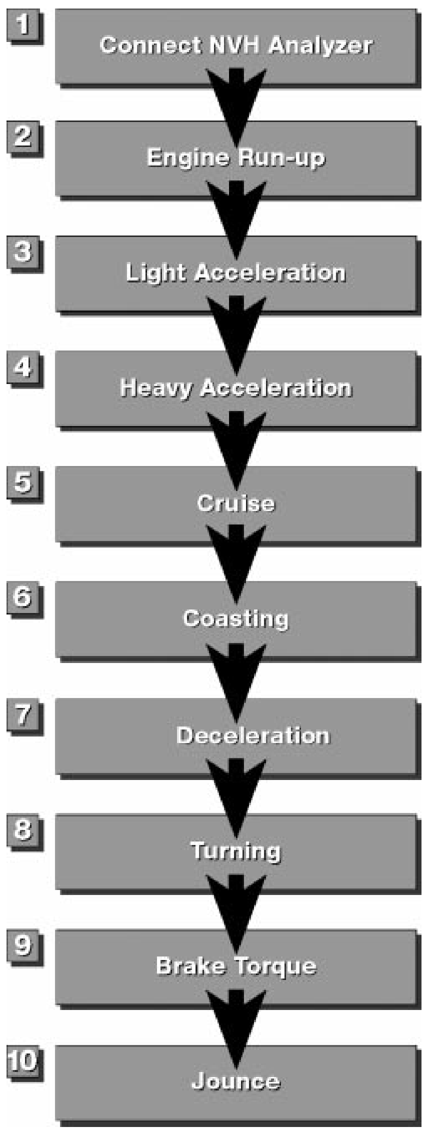
Diagnostic Description: **Road Test with the NVH Analyzer Microphone Function**

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.

Road Test Procedures

Fig. 2-24



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?

2D	BARCHART	3D
BEFORE		
ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE
AFTER		
ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE	ATTACH SCREEN PRINT HERE
COMMENTS		

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.*

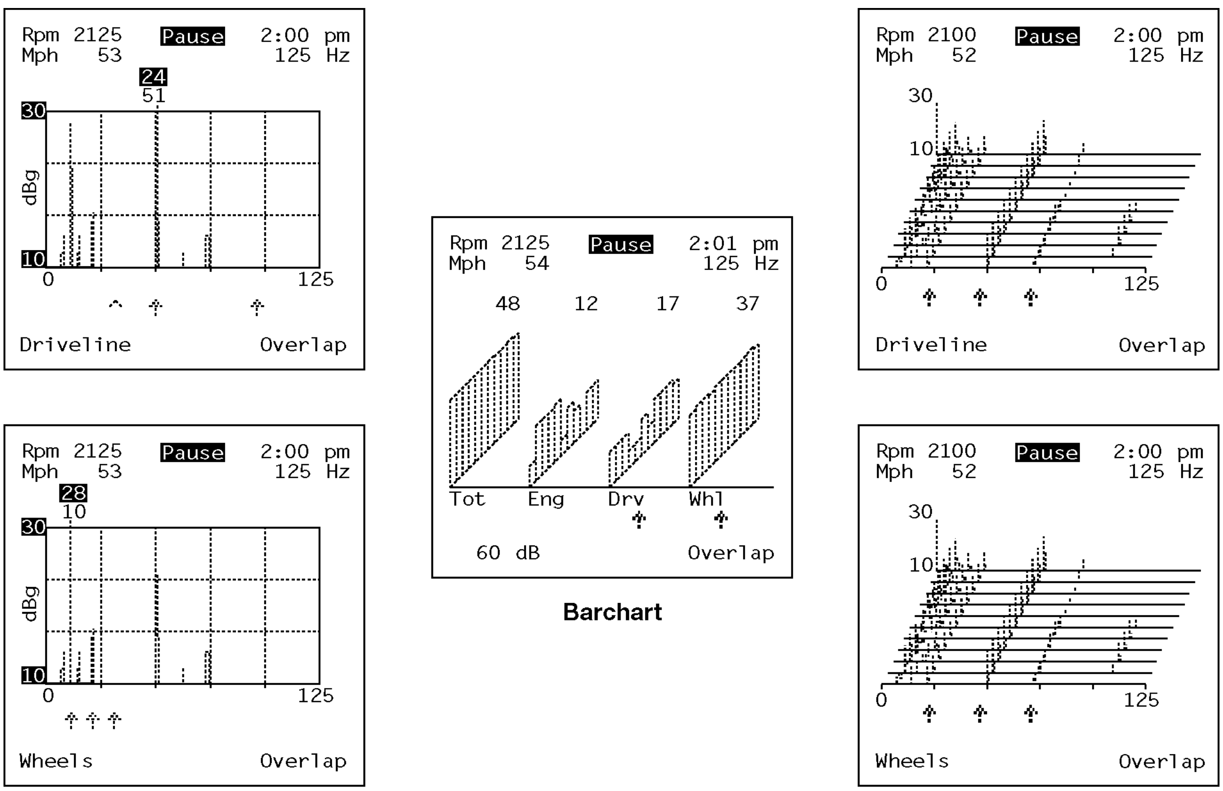
Case Study: Part III

Continued

The 3d display is consulted during the road test to follow the movement of the largest spikes while the operator alters the symptoms observed between 40 and 60 MPH. We verify that the spikes in question are ***vehicle speed sensitive*** *versus engine speed sensitive. When the driver shifts the vehicle to neutral, at the point when the symptoms are most noticeable, the spikes remained.*

4Runner Scenario

Fig. 2-25



2d **Barchart** **3d**

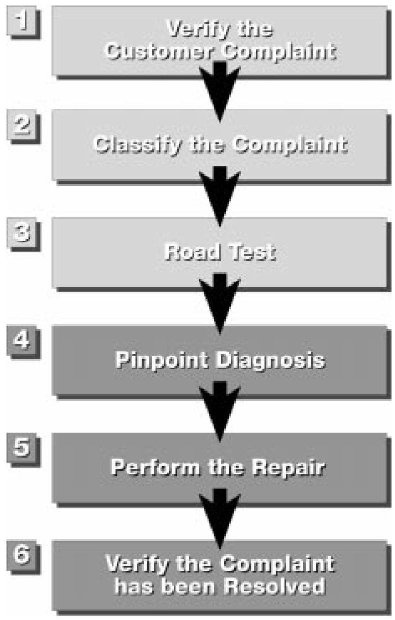
The data indicates that there are ***two possible conditions*** *contributing to the complaint. One in the area of* ***wheels*** *and the other in the area of* ***driveline****.*

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****.*

Section 3

PINPOINT DIAGNOSIS



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.

Visual Inspection
Continued

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.

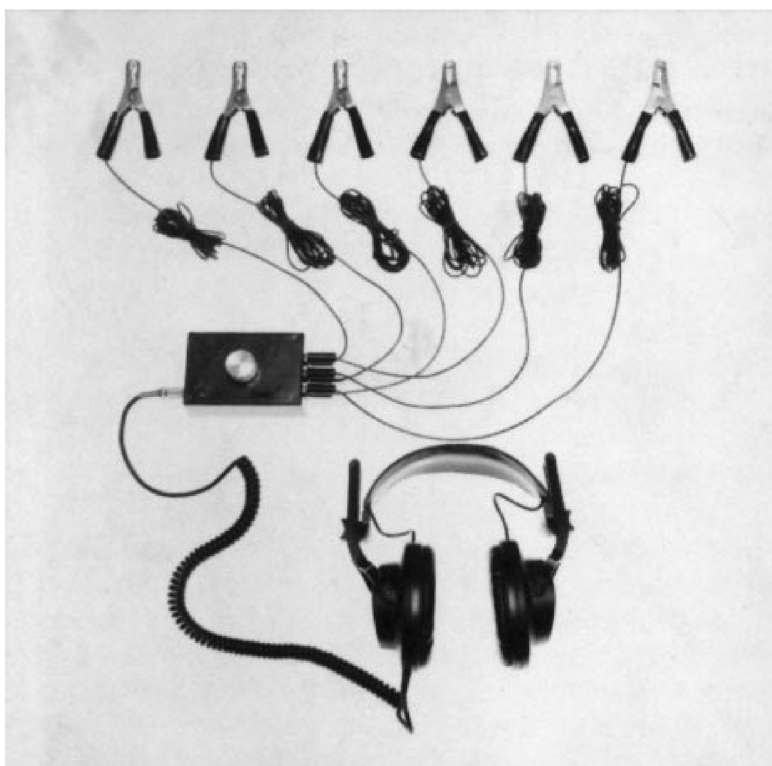
Examples include:

- 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.

Stethoscope

Fig. 3-1



Visual Inspection
Continued

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.

Visual Inspection

Fig. 3-2

Pinpoint Diagnosis by Source and Symptom Charts

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.

NOTE Refer to the end of this section for the charts.

Summary

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.

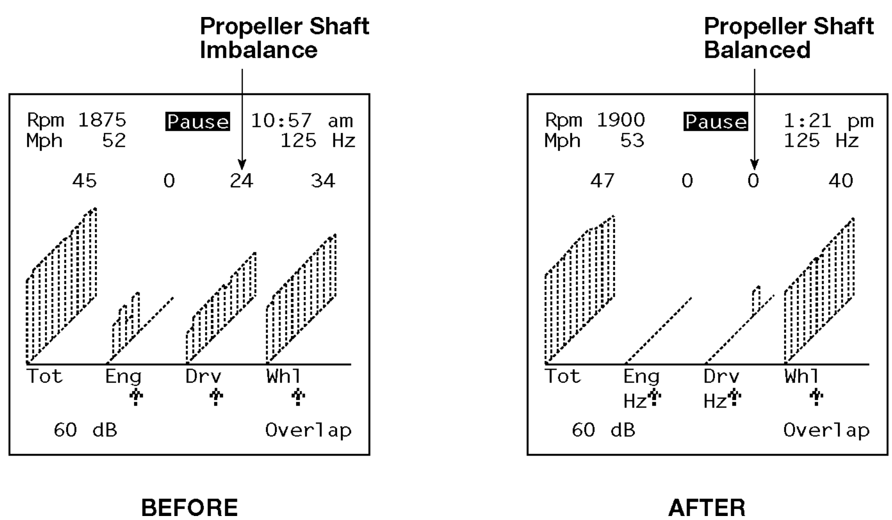
If you cannot objectively verify that the complaint has been resolved, then the opportunity exists to go back through the process to find the condition, without the customer's involvement.

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.

4Runner Scenario Screen Print

Fig. 3-3

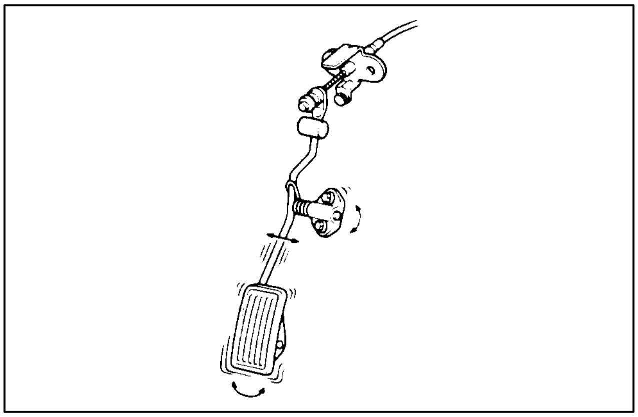


The next section of the course will deal with the common NVH repair techniques in greater depth.

Engine Symptoms Pinpoint Diagnosis

Symptom **Accelerator Pedal Vibration**

Description



Accelerator Pedal Vibrations
Fig. 3-4

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

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:

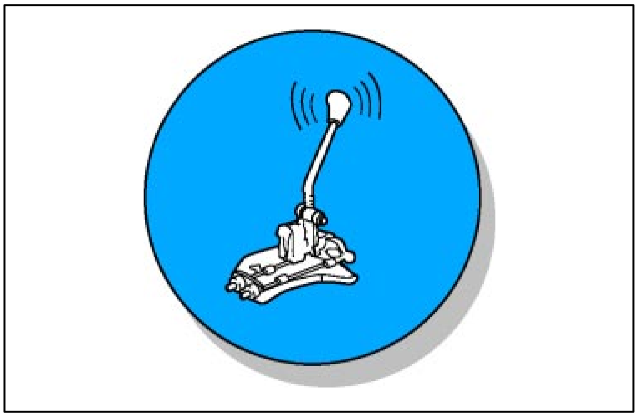
- the engine, transmission and accessories for contact with the body
- throttle lever and accelerator cables
  - check brackets, bushing and grommet
  - disconnect cable clamp and A/T throttle cable and see if the vibration changes. If the vibration disappears when the A/T throttle cable is disconnected 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.

Symptom **Shift Lever Vibrations**

Description



Shift Lever Vibrations
Fig. 3-5

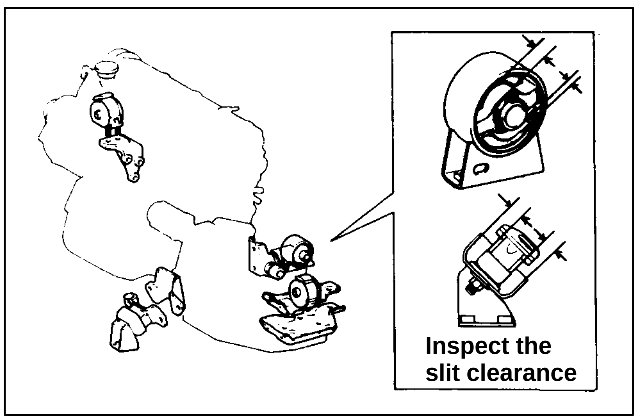
Shift lever vibrations are generated by engine torque fluctuations or imbalance of revolving or reciprocating engine components.

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:

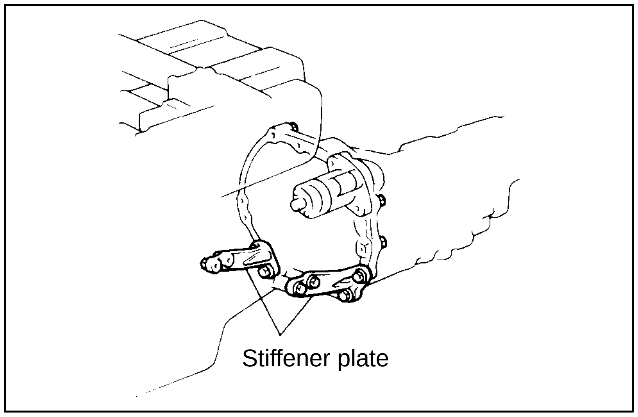


Mounts
Fig. 3-6

- 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

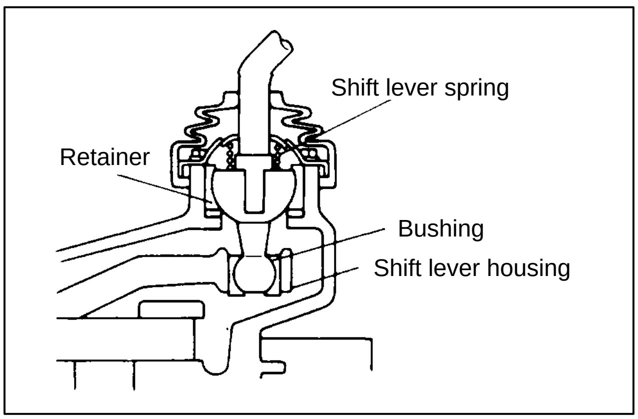
Pinpoint Diagnosis

Continued



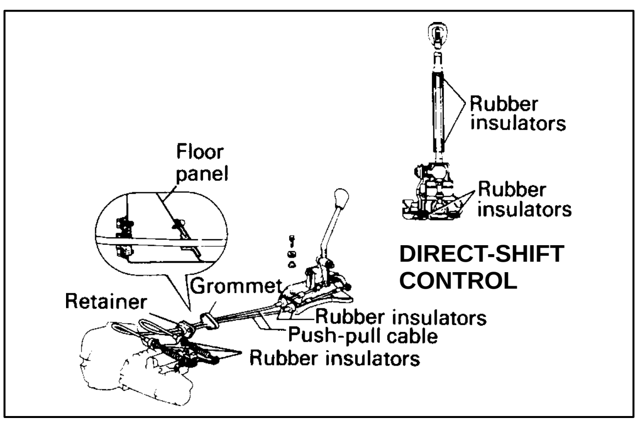
Stiffener Bracket
Fig. 3-7

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



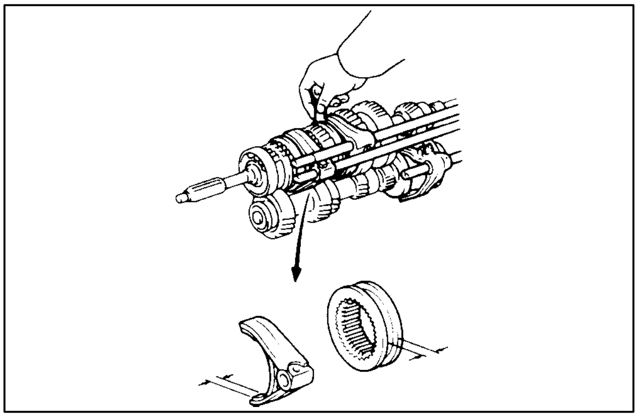
Shift Lever
Fig. 3-8

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



Linkage
Fig. 3-9

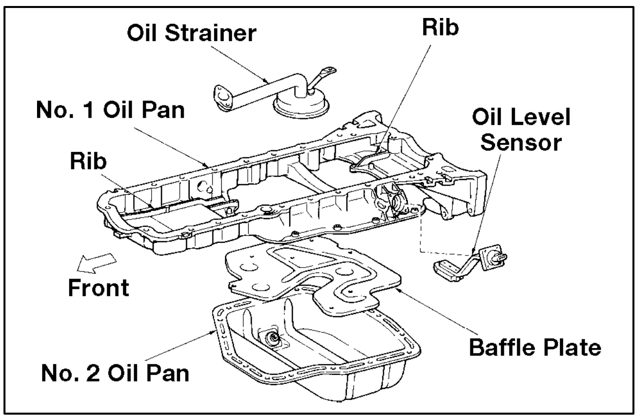
- shift control linkage and cable
  - check for bent linkage and excessive play
  - cables need to be checked for proper flex, contact with other components and excessive play



Transmission Condition
Fig. 3-10

- transmission condition
  - check for play in the shift fork and shaft
  - inspect each gear and thrust clearance
  - shift fork to hub sleeve clearance

Remarks

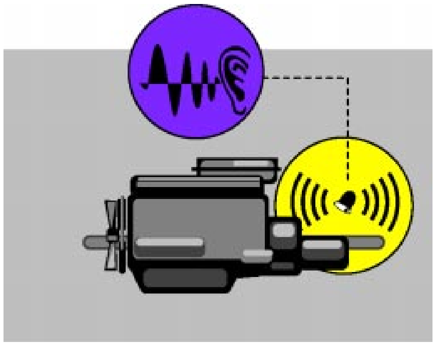


Two Piece Oil Pan
Fig. 3-11

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

Symptom **Engine Noise**

Description



Engine Noise
Fig. 3-12

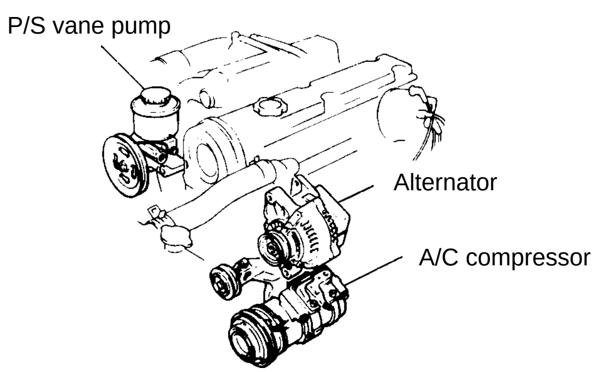
Engine noise is engine speed related and may require a change in load.

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:



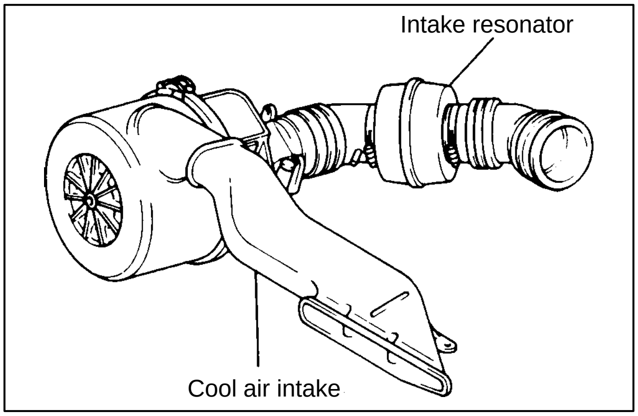
Engine Accessories
Fig. 3-13

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

CAUTION Perform diagnosis quickly when belts are removed so that problems such as overheating will not occur.

Pinpoint Diagnosis
Continued

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.



Intake System
Fig. 3-14

A technician can inspect the air intake system:

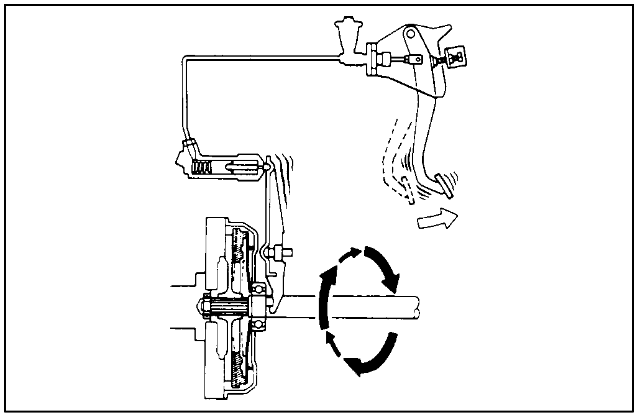
- for the proper components properly connected
- to see if the complaint can be modified by pushing on or disconnecting components or hoses
- for proper mounting and mount condition
- for foreign material that can make noise or cause an obstruction

Remarks

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

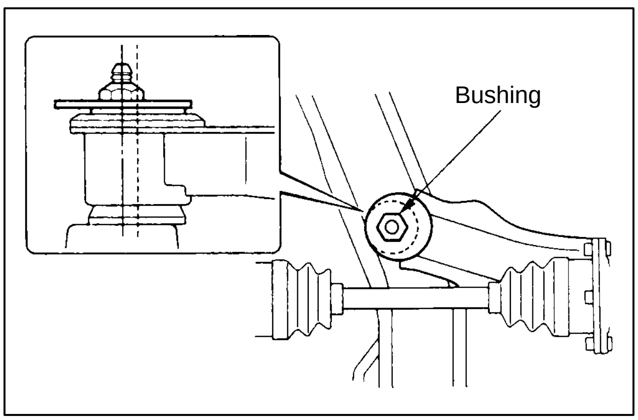


Clutch Judder
Fig. 3-15

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

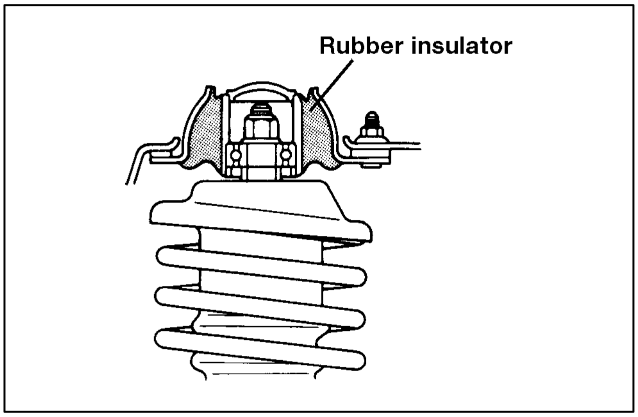
Engine running condition needs to be considered as well as the condition of the motor mounts when troubleshooting engine noise.



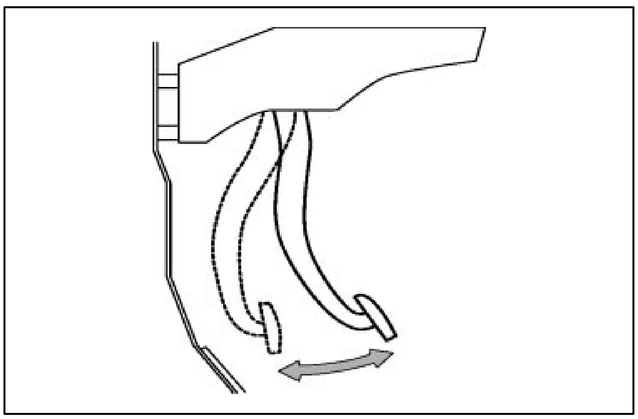
Bushing Contacts and Slits
Fig. 3-16

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

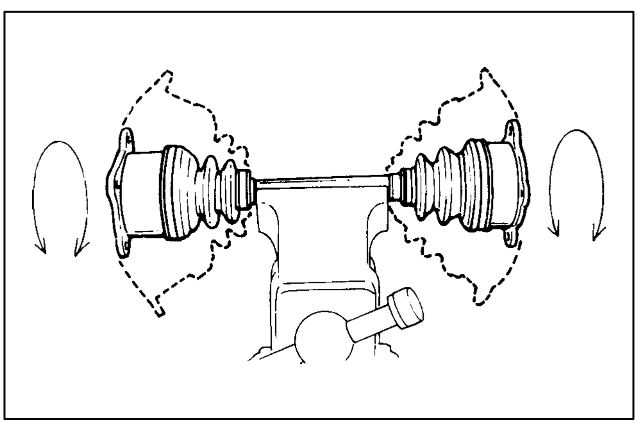


Rubber Insulator
Fig. 3-17



Clutch Pedal Free Play
Fig. 3-18

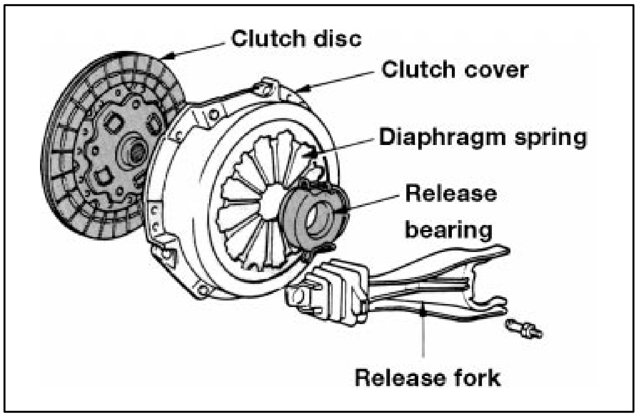
The pedal height, free play and movement need to be checked while operating the pedal. Repair manual procedures contain the specifications should an adjustment be required.



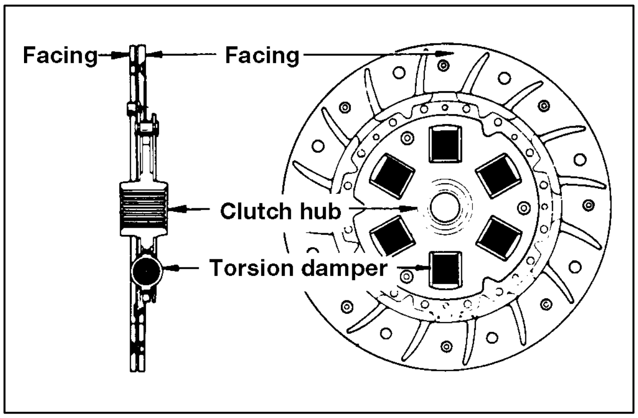
Driveshaft
Fig. 3-19

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

Pinpoint Diagnosis
Continued



Clutch Assembly
Fig. 3-20



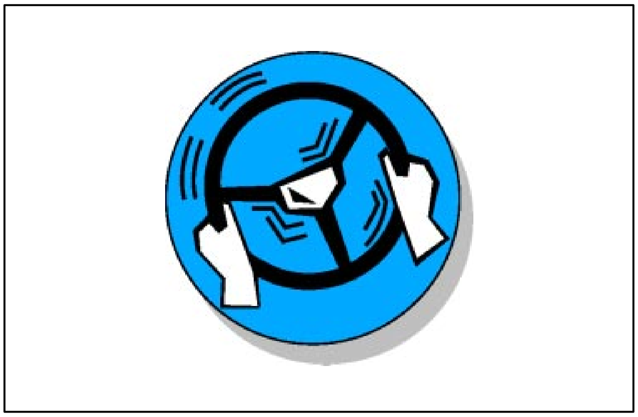
Clutch Disc
Fig. 3-21

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



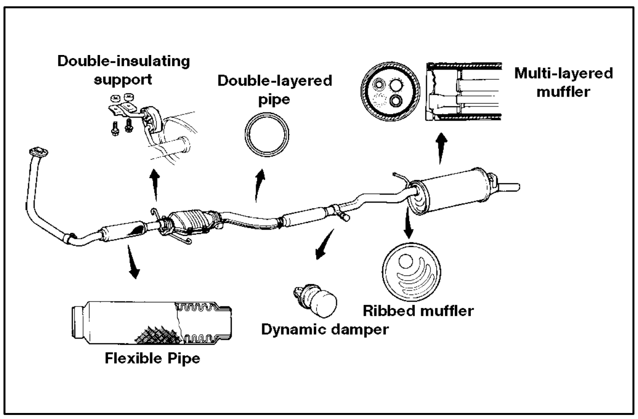
Take-Off Vibration
Fig. 3-22

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

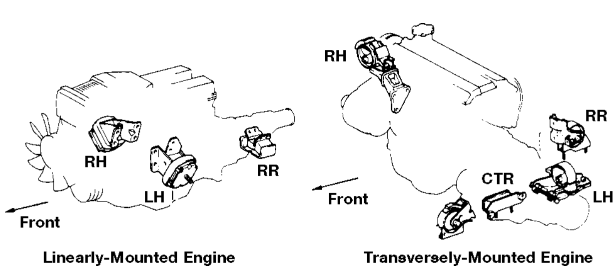
Torque fluctuations are transmitted to the body through the following areas:



Exhaust System Inspection
Fig. 3-23

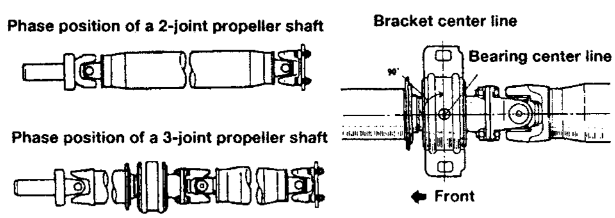
- The exhaust system needs to be checked:
  - when it is both cold and hot because it will expand and contract with temperature
  - for overall exhaust system tension by looking at the load on each rubber mount. Loosening the entire system to relax the tension and retightening it is effective in resolving 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.



Propeller Shaft Inspection
Fig. 3-24

- 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.

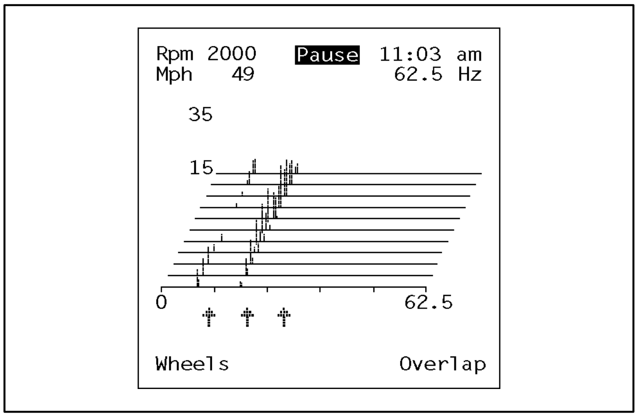
While duplicating the noise, see if it changes while modifying the intake air duct system, such as disconnecting or pushing on it.

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.

Symptom **Body Beating Noise**

Description



Beating
Fig. 3-26

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.

Pinpoint Diagnosis

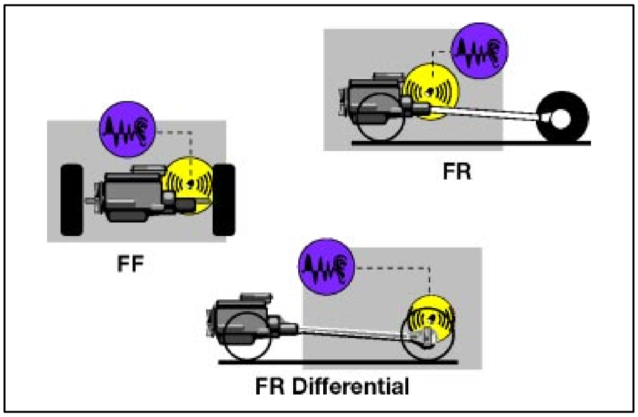
The specific pinpoint tests for the engine vibration are the same as those for body booming noise. In addition, the engine and transmission tightening and the stiffener bracket should also be inspected.

Driveline Pinpoint Diagnosis

Symptom

Transmission Gear Whine and Differential Gear Whine

Description



Gear Whine
Fig. 3-27

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.

Pinpoint Diagnosis

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.

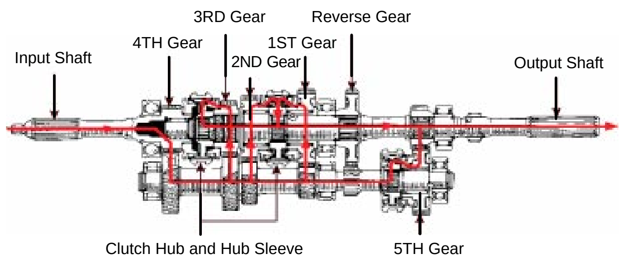
The transmission path is an important area of pinpoint diagnosis for both transmission and differential gear whine. Inspection of components that could transmit noise to the passenger compartment will often resolve the complaint.

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.

Pinpoint Diagnosis
Continued

Remarks



Gears
Fig. 3-28

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.

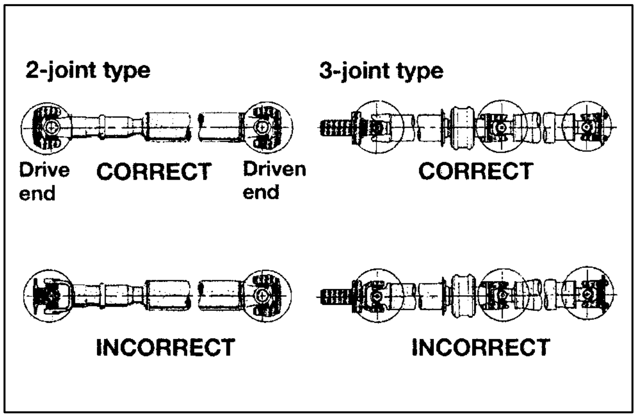
Gear whine and bearing noise are very similar, depending on the condition of the bearings, and difficult to isolate in a test drive. Bearing condition could also have an effect on gear mesh and condition.

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.

Symptom **Body Booming Noise**

Description



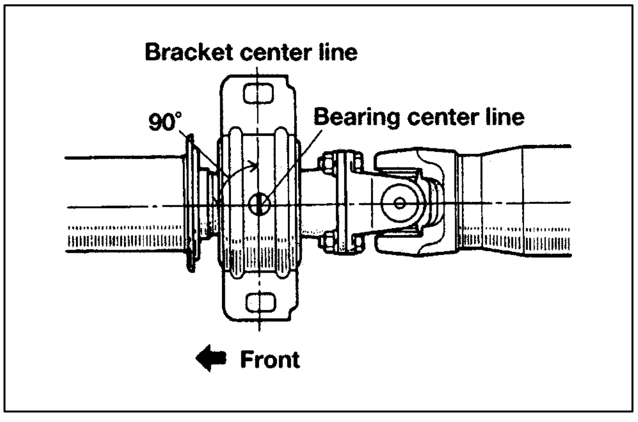
U-Joint Phase
Fig. 3-29

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.



Center Carrier
Fig. 3-30

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

Pinpoint Diagnosis
Continued

Remarks

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.

Symptom

Body Beating Noise

Description

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

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

Description

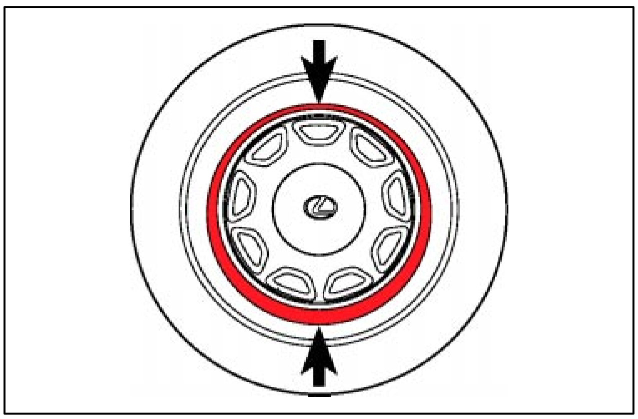
Body Shake, Steering Flutter and Steering Shimmy complaints all involve pinpoint diagnosis of the same components. The condition of the component is what determines which of the symptoms occur.

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

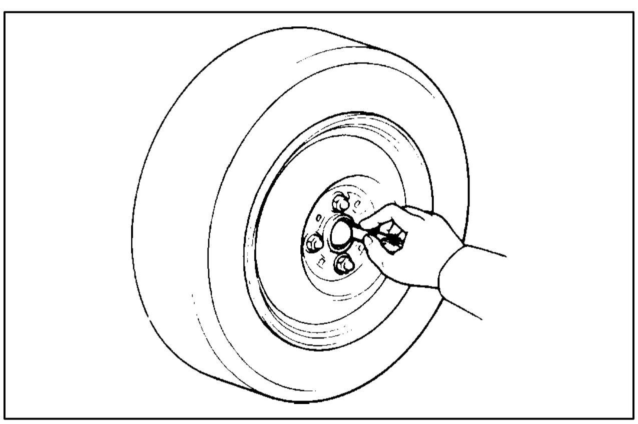
Tire and wheel inspection includes:

- 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.



Bead Seating
Fig. 3-31

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



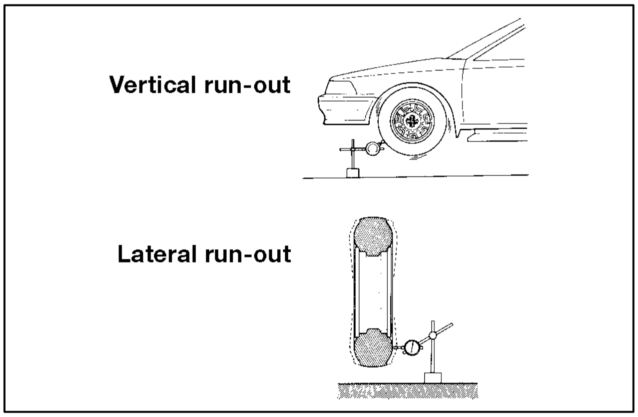
Hub to Wheel Centering
Fig. 3-32

- 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.

Pinpoint Diagnosis
Continued

There are two types of runout to check on the tires, wheels and hubs:

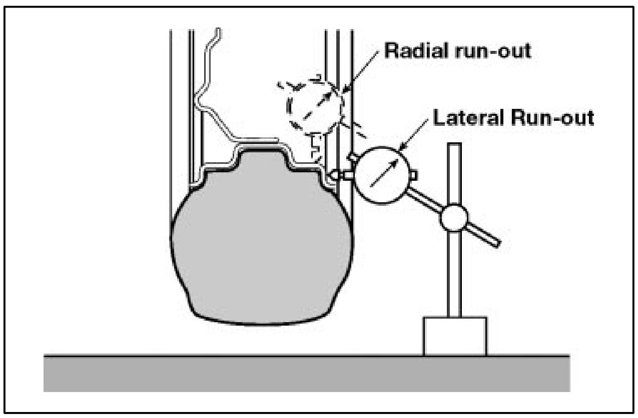
- radial
- lateral



Wheel and Tire Runout
Fig. 3-33

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.



Rim and Tire Runout
Fig. 3-34

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).

Pinpoint Diagnosis
Continued

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

Remarks

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.

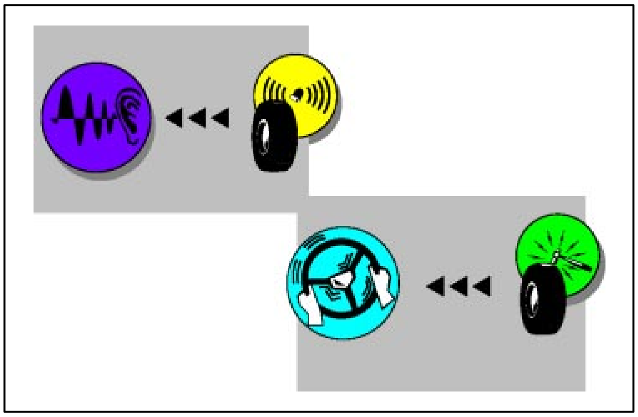
Details on measuring and correcting runout are discussed in Section 4.

Details on balancing are also included in Section 4.

Symptom

Riding Comfort, Harshness, Road Noise, Tire Pattern Noise

Description

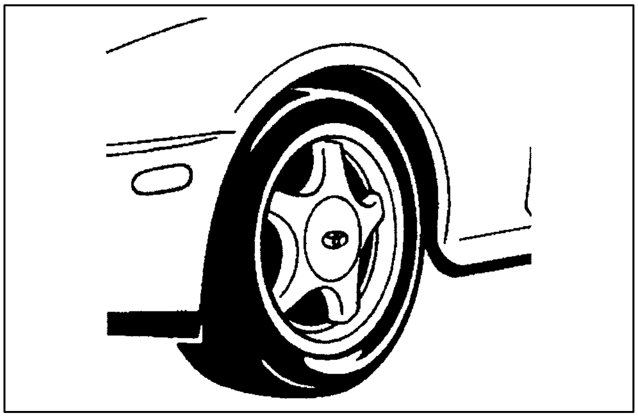


Harshness
Fig. 3-35

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**.

Pinpoint Diagnosis



Low Profile Tire
Fig. 3-36

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.

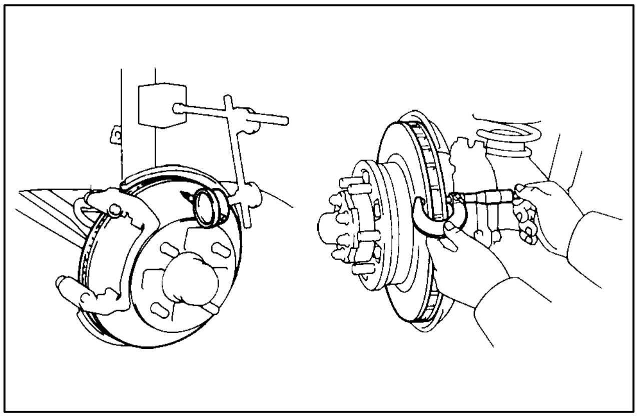
For example:

> 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.

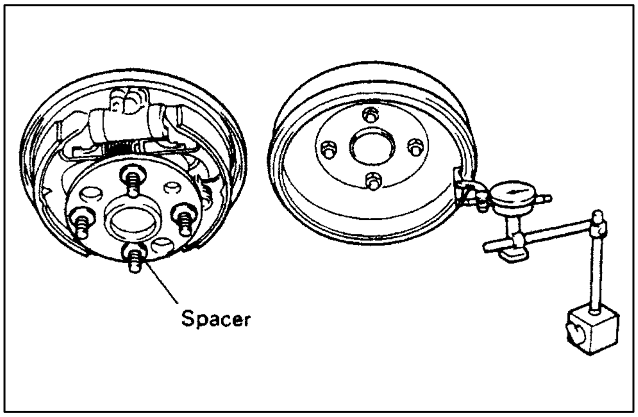
Symptom **Brake Vibration**

Description

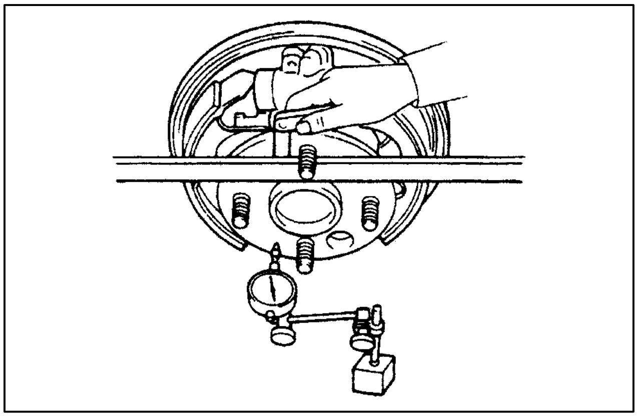
Brake vibration occurs only when the brakes are applied. As a result the technician can go directly to pinpoint diagnosis.



Rotor Runout and Thickness
Fig. 3-37



Drum Runout
Fig. 3-38



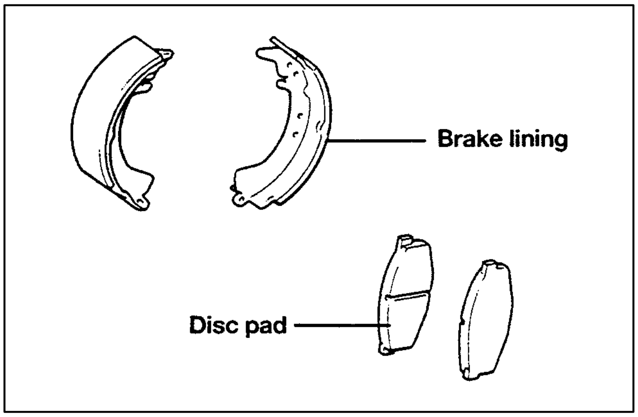
Axle Runout
Fig. 3-39

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**

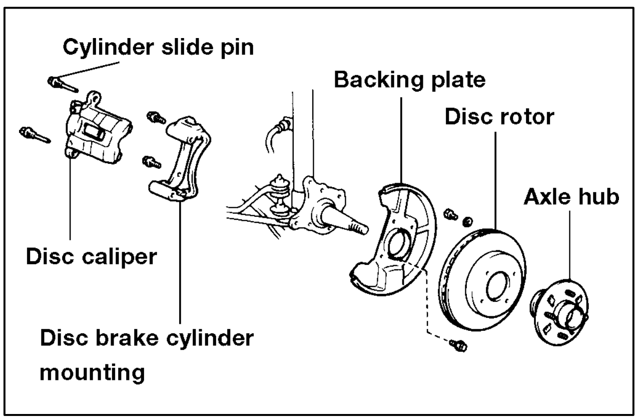
Description Brake squeak is associated with the contact of the pads/shoes to the rotors/drums.



Pad and Shoe Condition
Fig. 3-40

Inspection and repair involves inspection of:

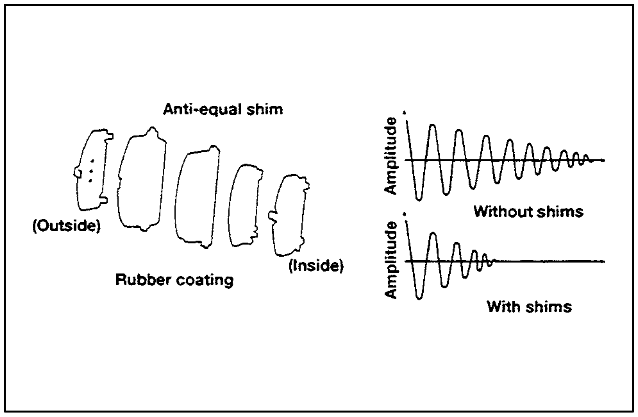
- The surface of the linings and pads for wear, hardness, and shine.
- Pad/shoe contact, by placing them against the rotor/drum surface and noting even contact.



Component Condition
Fig. 3-41

- Brake component tightness including the backing plate, hub and rotor, caliper mounting and slide pins.

Pinpoint Diagnosis
Continued



Brake Pad Anti-squeal Shims
Fig. 3-42

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

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

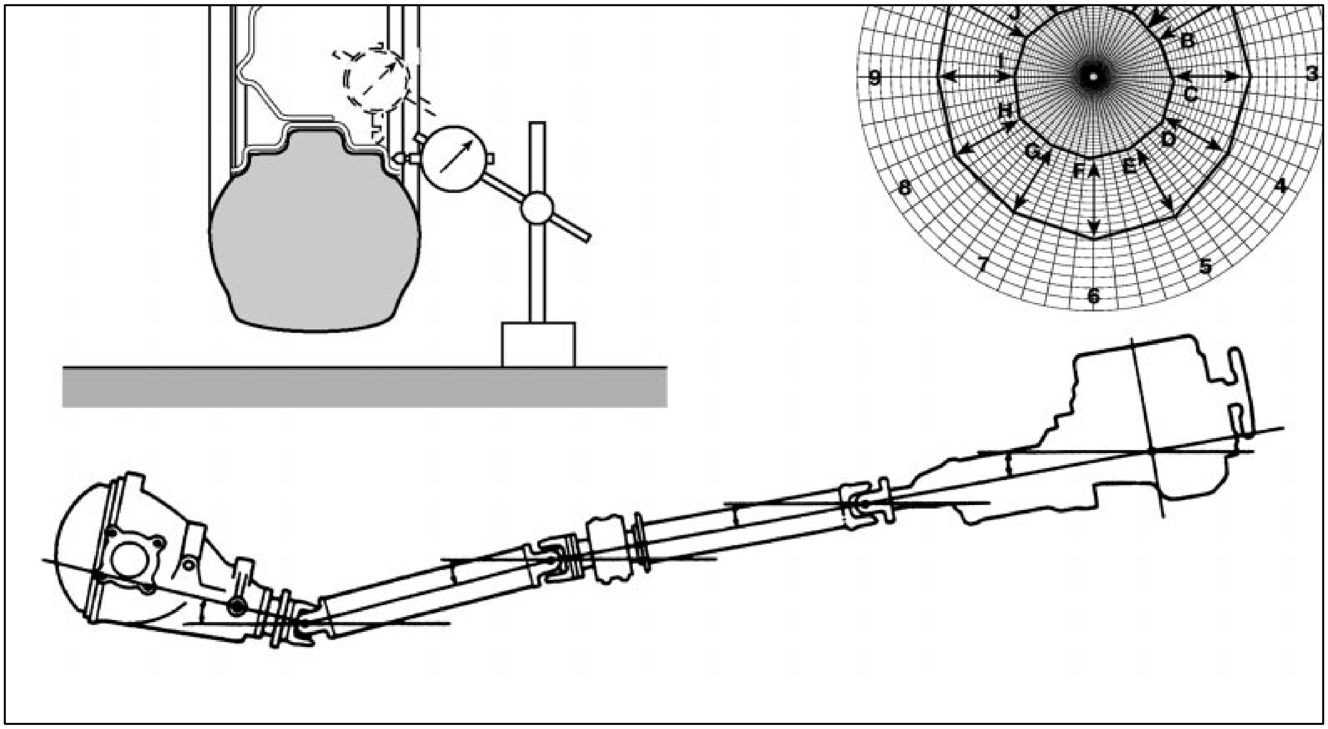
Description Body booming noise and Body beating noise are symptoms that can originate from wheels and tires. Body booming noise from tire uniformity and a tire/wheel vibration can also be one of the two vibrations required for body beating noises.

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.

Section 4

NVH REPAIR TECHNIQUES



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

CONDITION	DESCRIPTION
Driveline Propeller Shaft Imbalance	Propeller shaft imbalance is one of the major causes of a **first order driveline vibration**.
Driveline Runout	Runout can also cause a **first order driveline vibration**. 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.

REPAIR TECHNIQUE	REMARKS
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	**Always** refer to the **repair manua**l 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 availabl**e to insure customer satisfaction.
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.	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)

CONDITION	DESCRIPTION
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.

REPAIR TECHNIQUE	REMARKS
Horizontal 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. **Vertical** 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. 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.	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. 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. 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.
Before balancing a tire and wheel the following should be checked: • damage or deformed tires and wheels • foreign matter on the rim especially on the inside of the rim • all the existing weights are removed • 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 • the tread for plugs that may cause an imbalance or locate a broken cord • heavy or large custom and locking lug nuts 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.	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. 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.

Repair Techniques Chart (continued)

CONDITION	DESCRIPTION
Wheel and Tire Runout • lateral • radial	Wheel and tire runout (lateral/radial) will also generate a **first order vibration** 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.
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.

REPAIR TECHNIQUE	REMARKS
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.	The technician must keep in mind that runout, visible at the tire, can also be caused by other components such as the rim or axle.
Toyota has 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.	

Notes

WORKSHEET #5
Propeller Shaft Runout

Repair Technique: **Propeller Shaft Runout Measurement**

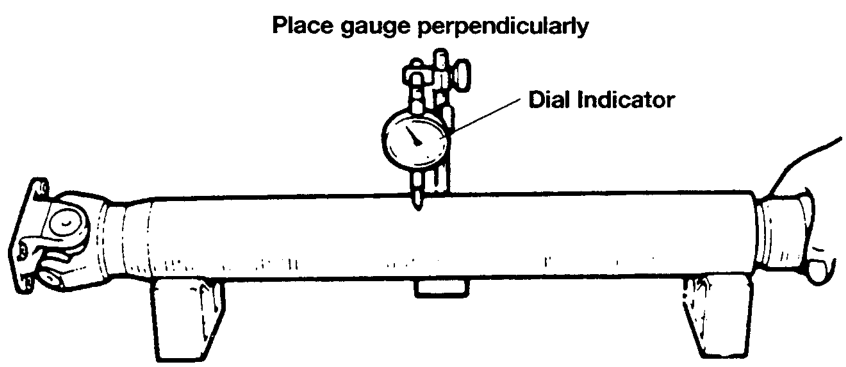
First order driveline vibrations are commonly caused by propeller shaft **imbalance** or **runout**. **Second order** is commonly associated with **U-joint** conditions.

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

Place gauge perpendicularly to shaft

Fig. 4-1



Instructions

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.

LOCATION / COMPONENT	FRONT	CENTER	REAR
INTERMEDIATE SHAFT			
PROPELLER SHAFT			
In "V" BLOCKS			
	VERTICAL	HORIZONTAL	
DIFFERENTIAL FLANGE			

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?

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**?

Notes

WORKSHEET #6A
Propeller Shaft Angle Measurement and Adjustment

Vehicle	Year/Prod. Date	Engine	Transmission

Description: **Vertical Joint Angles**

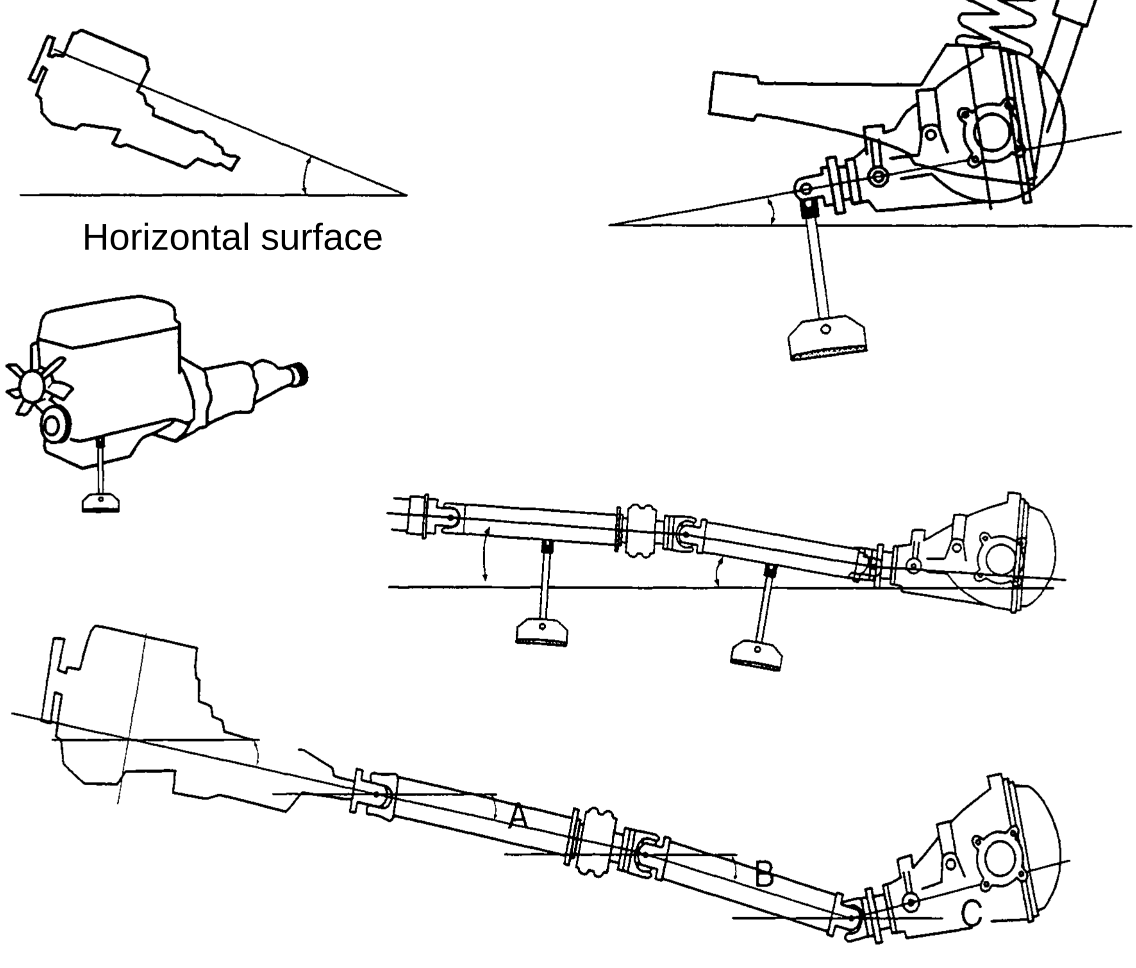
A propeller shaft angle condition is one of the causes of a **second order** driveline vibration. Angle measurement and adjustment involves the use of the **SST 09370-50010-10** and **shims**.

This worksheet is designed to provide **practice** in propeller shaft measurement and adjustment using the resources mentioned above.

Instructions

Vertical angle Measurement

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.

COMPONENTS	JOINT ANGLE
ENGINE/INTERMEDIATE SHAFT	(A)
INTERMEDIATE/PROPELLER SHAFTS	(B)
PROPELLER SHAFT/DIFFERENTIAL	(C)

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**.

THICKNESS	PART NUMBER
4.5 mm (0.177 in.)	90201-10008
6.5 mm (0.256 in.)	90201-10017
9.0 mm (0.354 in.)	90201-10033
11.0 mm (0.433 in.)	90201-10034
13.5 mm (0.532 in.)	90201-10035

Questions

1. What **adjustments** should be made to the following?

Engine mounts:	Up or Down
Rear transmission mounts:	Up or Down
Center carrier:	Up of 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

____

Notes

WORKSHEET #6B
Propeller Shaft Angle Measurement and Adjustment

Vehicle	Year/Prod. Date	Engine	Transmission

Description: **Horizontal Joint Angles**

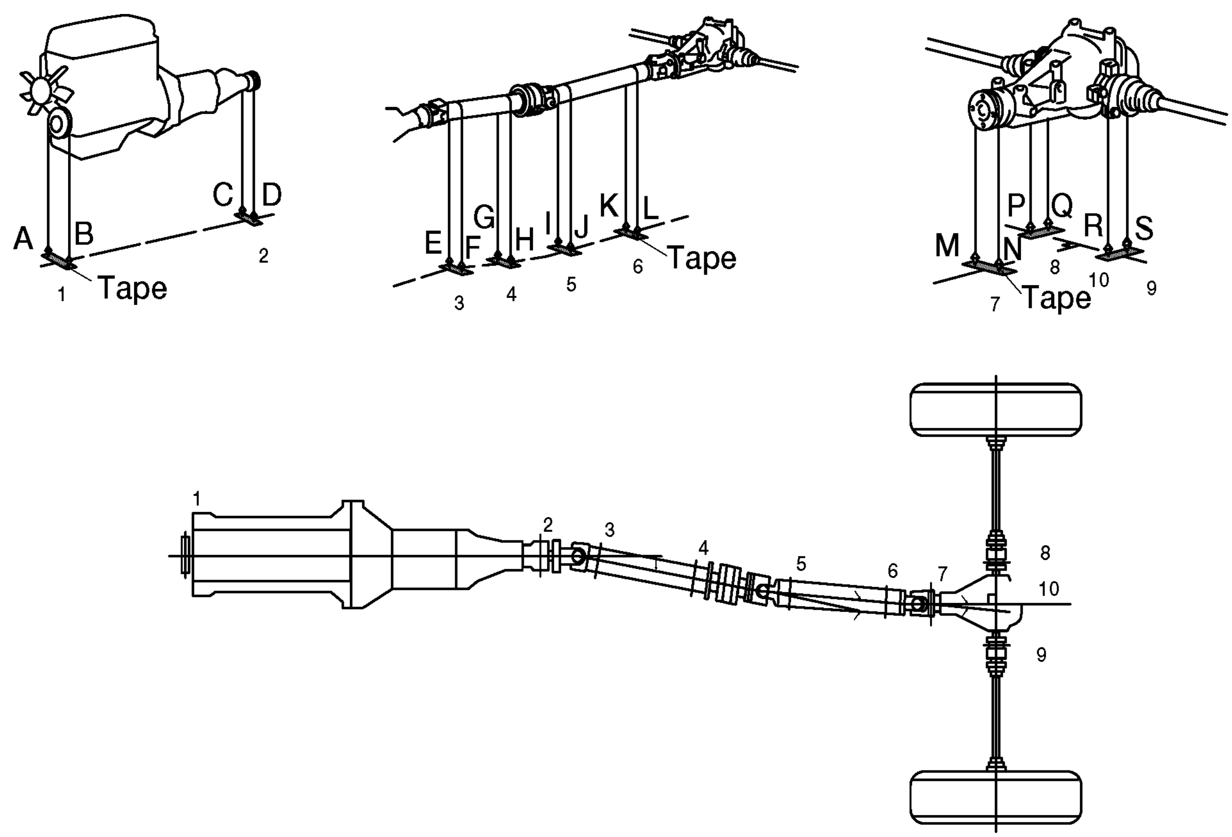
Horizontal joint angles can have the same impact on vibration as the vertical joint angles but are more difficult to measure. Due to the acceleration and deceleration of a joint as it rotates it is important to ensure that the working angles cancel these changes in speed and provide a smooth output and 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	JOINT ANGLE
ENGINE/INTERMEDIATE SHAFT	(A)
INTERMEDIATE/PROPELLER SHAFTS	(B)
PROPELLER SHAFT/DIFFERENTIAL	(C)

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?

WORKSHEET #7
Tire Runout Measurement and Phase Matching

Repair Technique: **Tire Runout Measurement and Phase Matching**

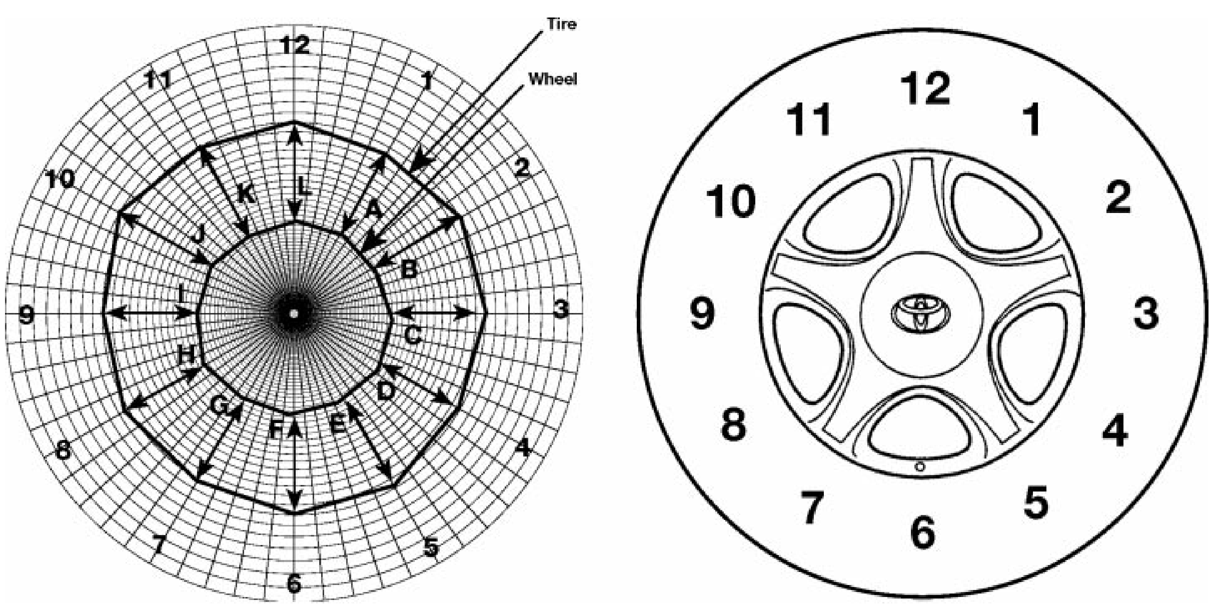
Runout can be one of the causes of tire and wheel vibrations, though not as common as balance. The technician has to be able to determine the **amount of runout**, the **component** causing it and if it can be resolved through phase matching or component replacement.

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



Instructions

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.

	TOTAL RADIAL RUNOUT BEFORE PHASE MATCHING	TOTAL RADIAL RUNOUT AFTER PHASE MATCHING	LATERAL RUNOUT
TIRE			
RIM			

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?

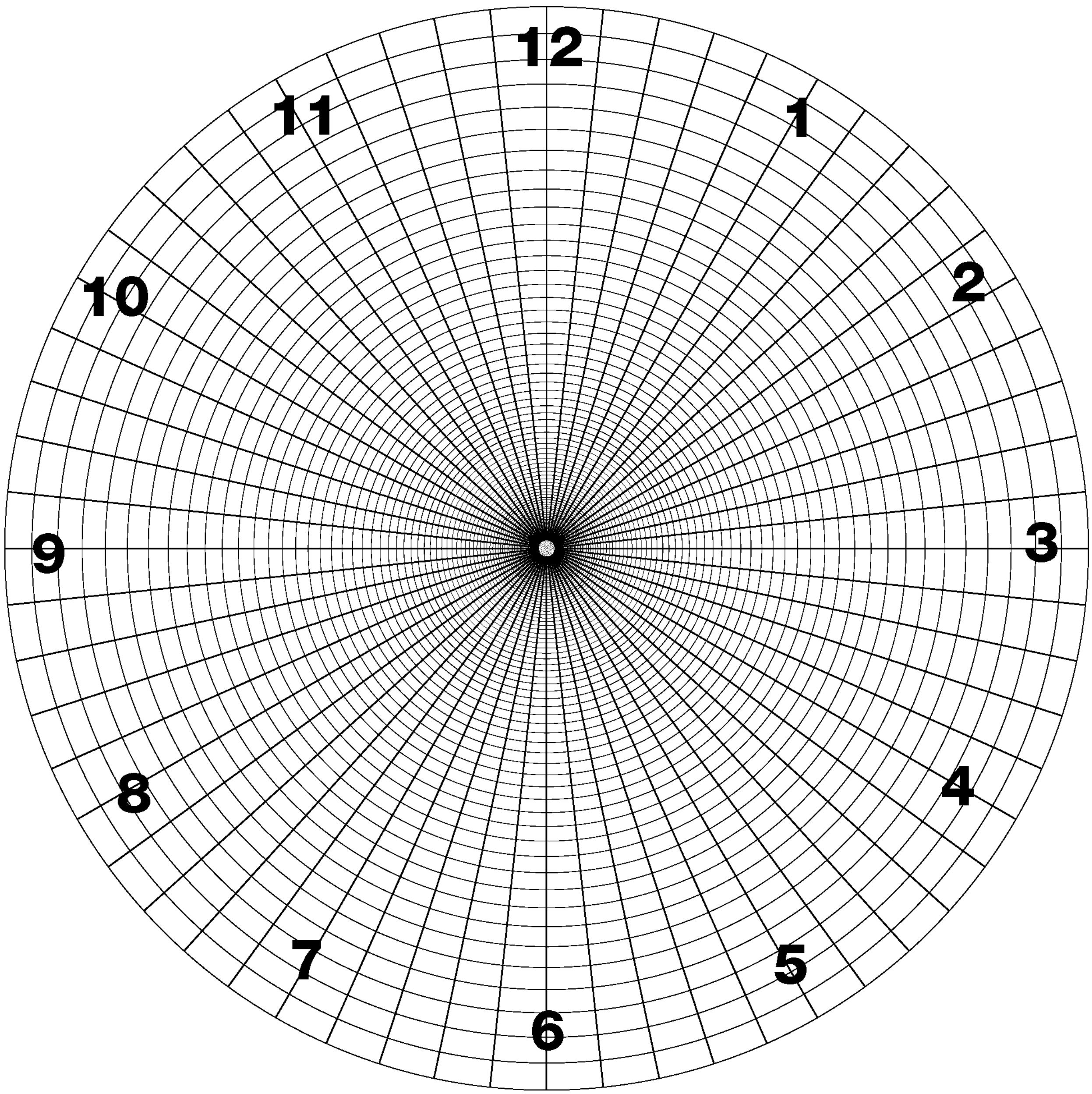
7. Why is it important to make sure the reference point for the tire and rim measurement are the **same** on the chart?

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?

Notes


12
1
2
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8
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11

Notes

WORKSHEET #8
Interior and Wind Noise

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.

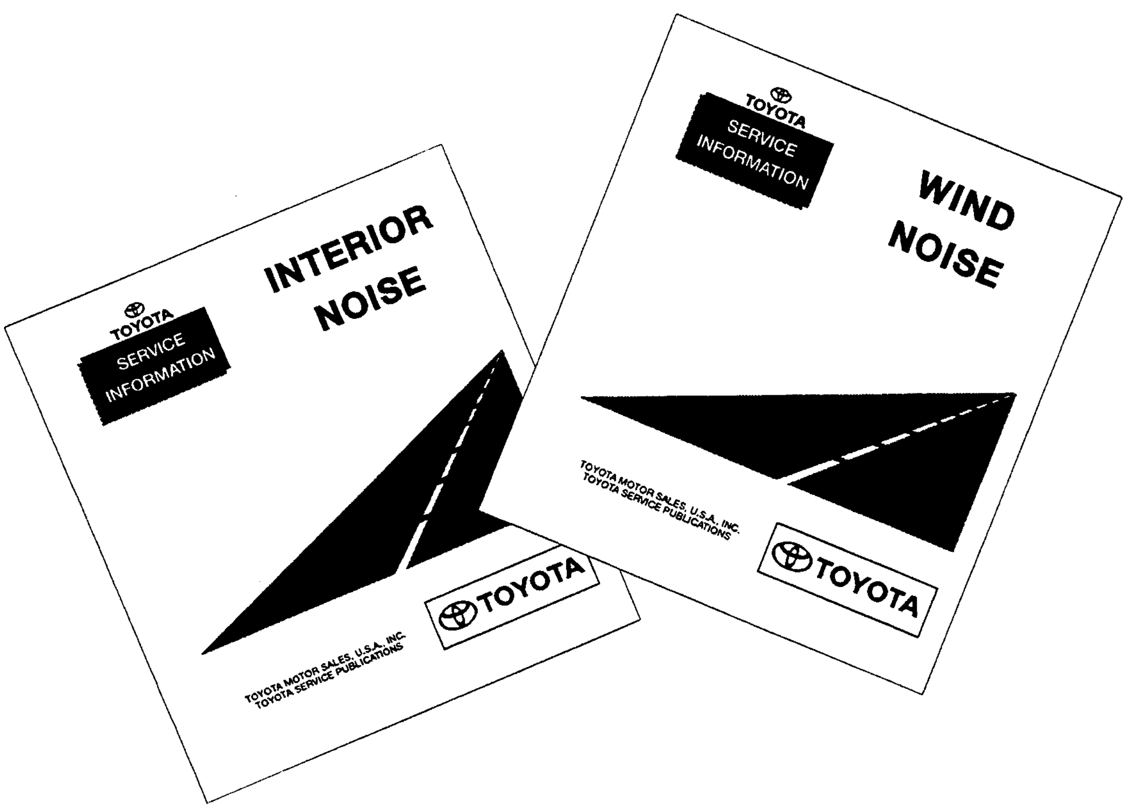
Toyota has published **two** excellent programs to assist the technician with diagnosing and repair of these conditions.

- 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.

Interior and Wind Noise Programs

Fig. 4-5



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

TOYOTA

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: ______________________________ 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

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

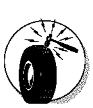
Where is it felt:

❍ 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? ____

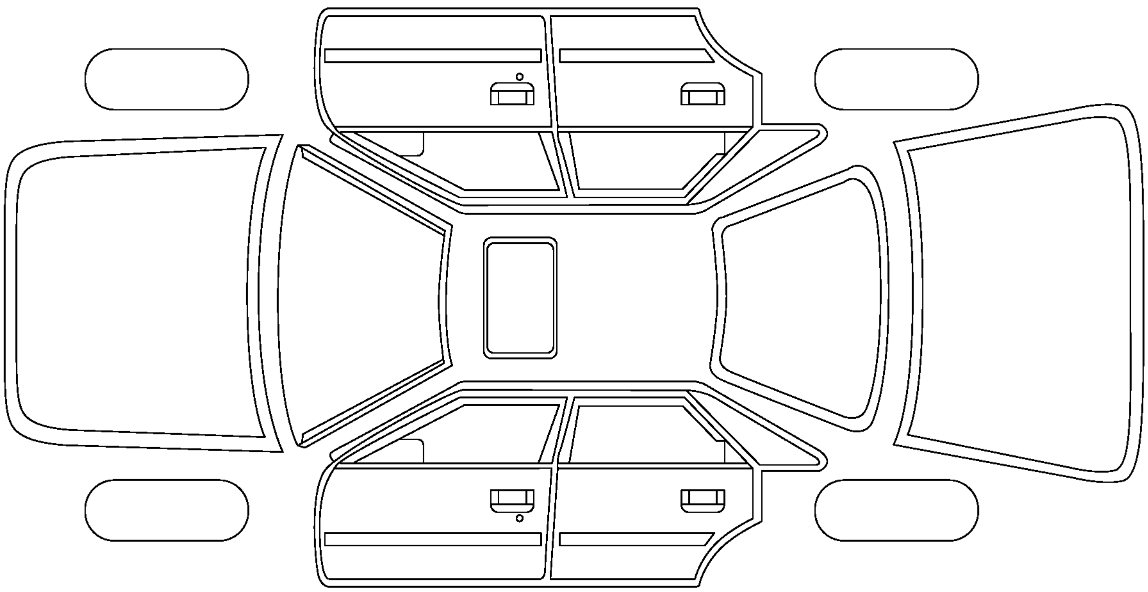
When do you experience it? ____

Has the vehicle ever been damaged? ❍ Yes ❍ No If so, please indicate where on the illustration.

Is there any relevent 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

____

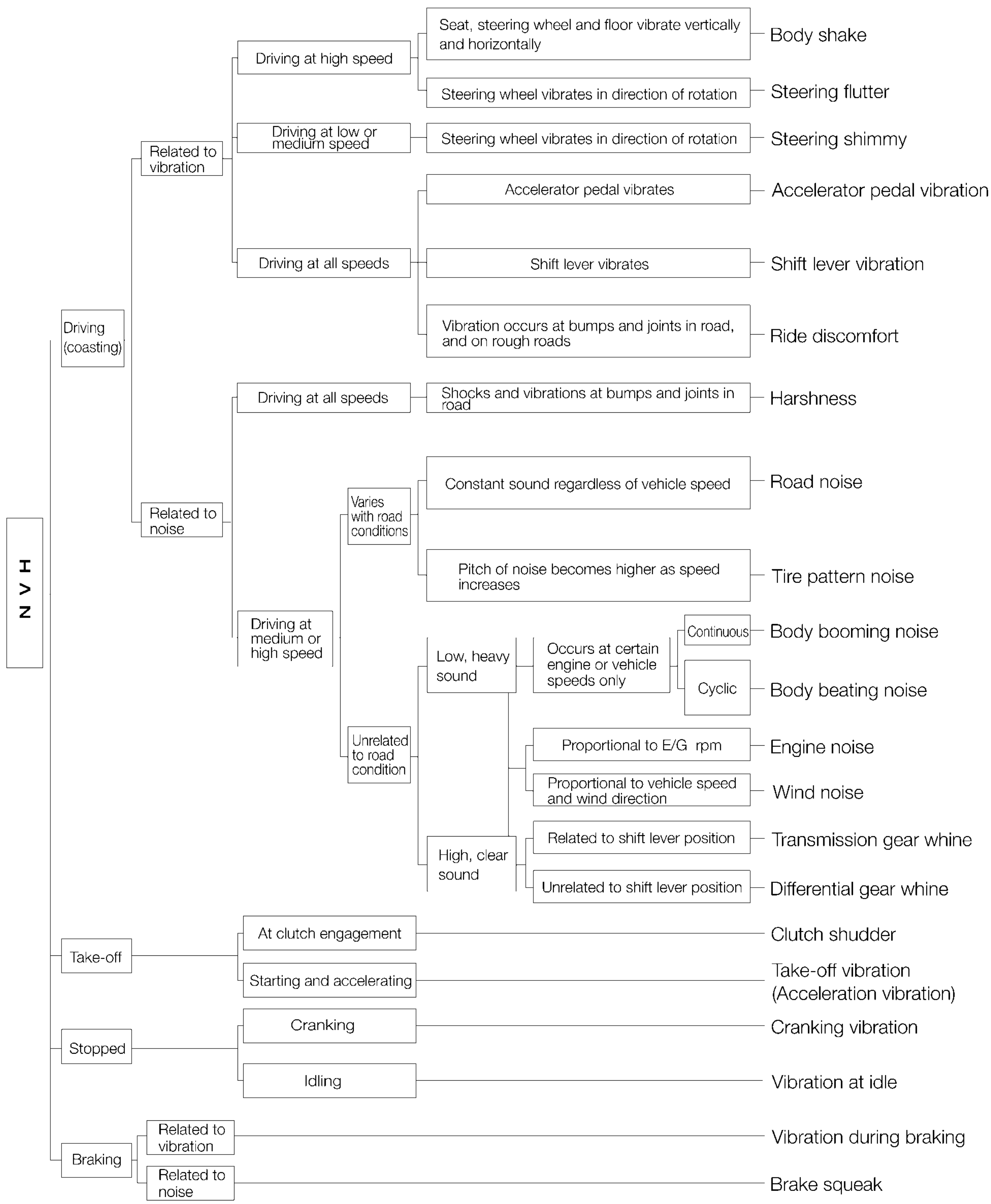
____

____

____

CLASSIFICATION FLOW CHART

TOYOTA

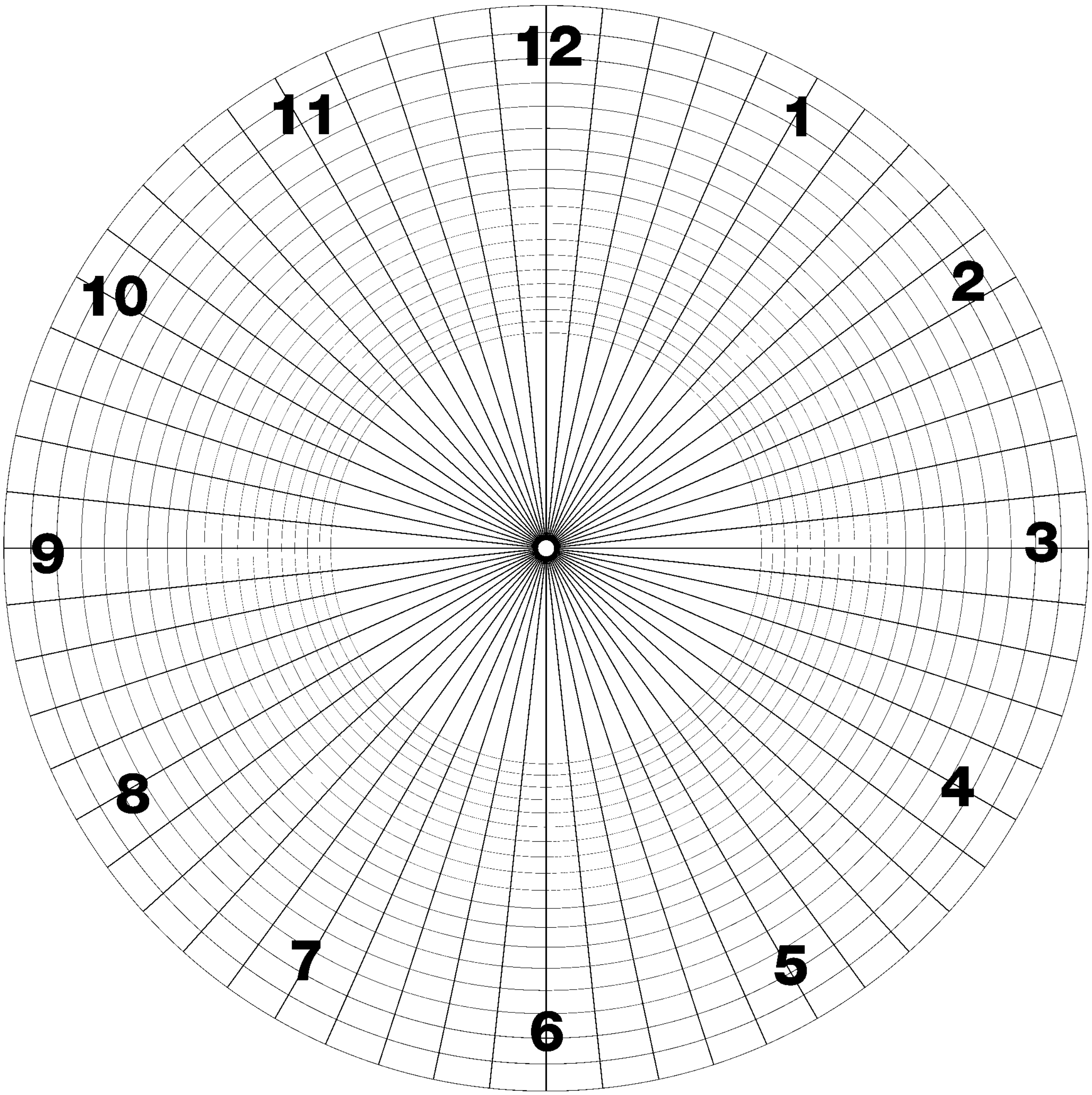


Appendix C

Radar Chart

RADAR CHART

TOYOTA



Appendix D
Specification Chart

SPECIFICATION CHART	
ITEM	**SPECIFICATION**
Tire runout	
Radial	1.0mm (0.039in.) max.
Lateral	1.2mm (0.047in.) max.
Wheel rim runout	
Radial	0.5mm (0.01 9in.) max.
Lateral	0.5mm (0.019in.) max.
Hub runout	
Radial	0.05mm (0.002in.) max.
Lateral	0.05mm (0.002in.) max.
Hub to wheel centering clearance	0.1mm (0.004in.) max.
Wheel rim mating surface flatness	0.1mm (0.004in) max.
Differential companion flange runout	
Vertical	0.05mm (0.002in.) max.
Horizontal	0.05mm (0.002in.) max.
Differential	
Ring gear runout	0.07mm (0.003in.) max.
Ring gear backlash	0.13 - 0.18mm (0.005 - 0.007in.)
Center bearing flange runout	0.05mm (0.002in.) max.
Universal joint play	0.05mm (0.002in.) max.
Propeller shaft runout	0.8mm (0.032in.) max.
Torque converter sleeve runout	0.3mm (0.012in.) max.
Drive plate runout	0.2mm (0.008in.) max.
Brake Rotor	
Runout	0.1mm (0.004in.) max.
Thickness	0.01mm (0.0004in.) max.
Brake drum runout	0.1mm (0.004in.) max.
Axle hub and shaft	
Runout	0.05mm (0.002in.) max.
Surface flatness	0.05mm (0.002in.) max.

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.

F

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).

H

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)

I

Imbalance - Out of balance; unequal distribution of weight around a rotating object or component, causing a vibration.

J

Judder - A term commonly used to describe a low frequency vibration on a clutch on engagement. 10-20Hz

L

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.

M

Mass Damper - A mass fixed to a component to change the natural frequency of the component.

N

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

O

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.

P

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.

R

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.

S

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.

T

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.

V

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.

W

Working Angle - The angle formed by two rotating components such as a transmission and a propeller shaft.

Appendix F
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