Noise, Vibration and Harshness (NVH)

Noise is any undesirable sound, usually unpleasant in nature. Vibration is any motion, shaking or trembling, that can be felt or seen when an object moves back and forth or up and down. Harshness is a ride quality issue where the vehicle's response to the road transmits sharply to the customer. Harshness normally describes a firmer than usual response from the suspension system. Noise, vibration and harshness (NVH) is a term used to describe these conditions, which result in varying degrees of dissatisfaction. Although, a certain level of NVH caused by road and environmental conditions is normal. This section is designed to aid in the diagnosis, testing and repair of NVH concerns.

Acceptable Noise, Vibration and Harshness

All internal combustion engines and drivelines produce some noise and vibration; operating in a real world environment adds noise that is not subject to control. Vibration isolators, mufflers and dampers reduce these to acceptable levels. A driver who is unfamiliar with a vehicle can think that some sounds are abnormal when actually the sounds are normal for the vehicle type. For example, Traction-Lok® differentials produce a slight noise on slow turns after extended highway driving. This is acceptable and has no detrimental effect on the locking axle function. As a technician, it is very important to be familiar with vehicle features and know how they relate to NVH concerns and their diagnosis. For example, if the vehicle has automatic overdrive, it is important to test drive the vehicle both in and out of overdrive mode.

Diagnostic Theory

The shortest route to an accurate diagnosis results from:

- system knowledge, including comparison with a known good system.
- system history, including repair history and usage patterns.
- condition history, especially any relationship to repairs or sudden change.
- knowledge of possible sources.
- using a systematic diagnostic method that divides the system into related areas.

The diagnosis and correction of noise, vibration and harshness concerns requires:

- a road or system test to determine the exact nature of the concern.
- an analysis of the possible causes.
- testing to verify the cause.
- repairing any concerns found.
- a road test or system test to make sure the concern has been corrected or brought back to within an acceptable range.

Glossary of Terms

Acceleration — Light

An increase in speed at less than 1/2 throttle.

Acceleration — Medium

An increase in speed at 1/2 to nearly full throttle, such as 0-97 km/h (0-60 mph) in approximately 30 seconds.

Acceleration — Heavy

An increase in speed at 1/2 to full throttle, such as 0-97 km/h (0-60 mph) in approximately 20 seconds.

Ambient Temperature

The surrounding or prevailing temperature.

Amplitude

The quantity or amount of energy produced by a vibrating component (G force). An extreme vibration has a high amplitude. A mild vibration has a low amplitude.

Backlash

Gear teeth clearance.

Boom

Low frequency or low pitched noise often accompanied by a vibration. Also refer to drumming.

Bound Up

An overstressed isolation (rubber) mount that transmits vibration/noise instead of absorbing it.

Brakes Applied

When the service brakes are applied with enough force to hold the vehicle against movement with the transmission in gear.

Buffet/Buffeting

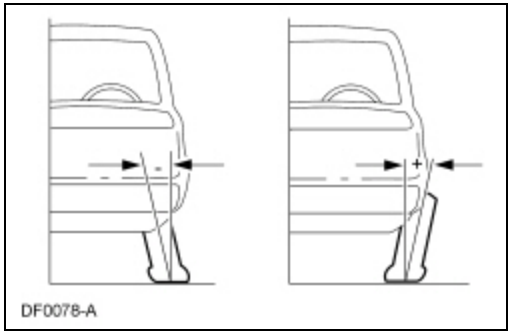
Strong noise fluctuations (less than 1000 Hz) caused by gusting winds. An example would be wind gusts against the side glass.

Buzz

A low-pitched sound (200-5000 Hz) like that from a bee. Often a metallic or hard plastic humming sound. Also describes a high frequency (200-800 Hz) vibration. Vibration feels similar to an electric razor.

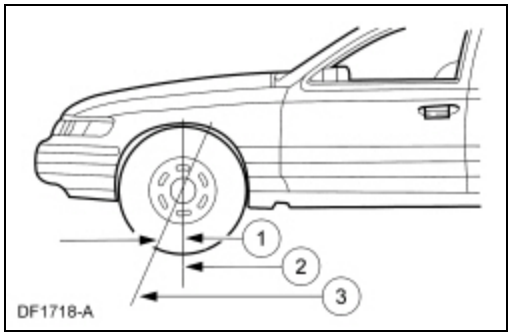
Camber

The angle of the wheel in relation to the true vertical as measured looking from the front of the vehicle. Camber is positive when the wheel angle is offset so that the top of the wheel is positioned away from the vehicle.



Caster

The angle of the steering knuckle in relation to the true vertical as measured looking from the side of the vehicle.



Item	Description
1	Positive caster
2	True vertical
3	Steering axis

Chatter

A pronounced series of rapidly repeating rattling or clicking sounds.

Chirp

A short-duration high-pitched noise associated with a slipping drive belt.

Chuckle

A repetitious low-pitched sound. A loud chuckle is usually described as a knock.

Click

A sharp, brief, non-resonant sound, similar to actuating a ball point pen.

Clonk

A hydraulic knocking sound. Sound occurs with air pockets in a hydraulic system. Also described as hammering.

Clunk/Driveline Clunk

A heavy or dull, short-duration, low-frequency sound. Occurs mostly on a vehicle that is accelerating or decelerating abruptly. Also described as a thunk.

Coast/Deceleration

Releasing the accelerator pedal at cruise, allowing the engine to reduce vehicle speed without applying the brakes.

Coast/Neutral Coast

Placing the transmission range selector in NEUTRAL (N) or depressing the clutch pedal while at cruise.

Constant Velocity (CV) Joint

A joint used to absorb vibrations caused by driving power being transmitted at an angle.

Controlled Rear Suspension Height

The height at which a designated vehicle element must be when driveline angle measurements are made.

Coupling Shaft

The shaft between the transfer case and the front drive axle or, in a 2-piece rear driveshaft, the front section.

CPS

Cycles per second. Same as hertz (Hz).

Cracks

A mid-frequency sound, related to squeak. Sound varies with temperature conditions.

Creak

A metallic squeak.

Cruise

Constant speed on level ground; neither accelerating nor decelerating.

Cycle

The process of a vibrating component going through a complete range of motion and returning to the starting point.

Decibel

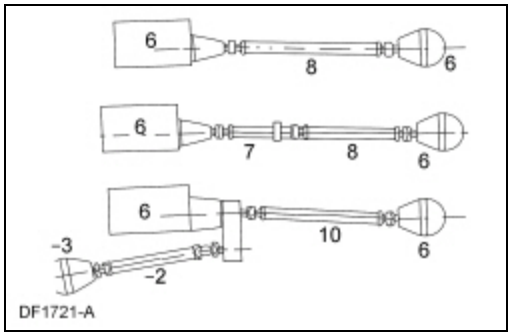
A unit of measurement, referring to sound pressure level, abbreviated dB.

Drive Engine Run-Up (DERU) Test

The operation of the engine through the normal rpm range with the vehicle standing still, the brakes applied and the transmission engaged. This test is used for noise and vibration checks.

Driveline Angles

The differences of alignment between the transmission output shaft, the driveshaft and the rear axle pinion centerline.



Driveshaft

The shaft that transmits power to the rear axle input shaft (pinion shaft). In a 2-piece driveshaft, it is the rearmost shaft.

Drivetrain

All power transmitting components from the engine to the wheels; includes the clutch or torque converter, the transmission, the transfer case, the driveshaft and the front or rear drive axle.

Drivetrain Damper

A weight attached to the engine, the transmission, the transfer case or the axle. It is tuned by weight and placement to absorb vibration.

Drone

A low frequency (100-200 Hz) steady sound, like a freezer compressor. Also described as a moan.

Drumming

A cycling, low-frequency (20-100 Hz), rhythmic noise often accompanied by a sensation of pressure on the ear drums. Also described as a low rumble, boom or rolling thunder.

Dynamic Balance

The equal distribution of weight on each side of the centerline, so that when the wheel and tire assembly spins, there is no tendency for the assembly to move from side-to-side (wobble). Dynamically unbalanced wheel and tire assemblies can cause wheel shimmy.

Engine Imbalance

A condition in which an engine's center mass is not concentric to the rotation center, causing excessive motion.

Engine Misfire

When combustion in one or more cylinders does not occur or occurs at the wrong time.

Engine Shake

An exaggerated engine movement or vibration that directly increases in frequency as the engine speed increases. It is caused by non-equal distribution of mass in the rotating or reciprocating components.

Flexible Coupling

A flexible joint.

Float

A drive mode on the dividing line between cruise and coast where the throttle setting matches the engine speed with the road speed.

Flutter

Mid to high (100-2000 Hz) intermittent sound due to air flow. Similar to a flag flapping in the wind.

Frequency

The rate at which a cycle occurs within a given time.

Gravelly Feel

A grinding or growl in a component, similar to the feel experienced when driving on gravel.

Grind

An abrasive sound, similar to using a grinding wheel, or rubbing sand paper against wood.

Hiss

Steady high frequency (200-800 Hz) noise. Vacuum leak sound.

Hoot

A steady low frequency tone (50-500 Hz), sounds like blowing over a long neck bottle.

Howl

A mid-range frequency (200-800 Hz) noise between drumming and whine. Also described as a hum.

Hum

Mid-frequency (200-800 Hz) steady sound, like a small fan motor. Also described as a howl.

Hz

Hertz; a frequency measured in cycles per second.

Imbalance

Out of balance; heavier on one side than the other. In a rotating component, imbalance often causes vibration.

Inboard

Toward the centerline of the vehicle.

Intensity

The physical quality of sound that relates to the strength of the vibration (measured in decibels). The higher the sound's amplitude, the higher the intensity and vice versa.

Isolate

To separate the influence of one component to another.

Knock

A heavy, loud, repetitious sound, like a knock on the door.

Moan

A constant, low-frequency (100-200 Hz) tone. Also described as a hum.

Neutral Engine Run-Up (NERU) Test

The operation of the engine through the normal rpm range with the vehicle standing still and the transmission disengaged. This test is used to identify engine related vibrations.

Neutralize/Normalize

To return to an unstressed position. Used to describe mounts. Also refer to bound up.

Outboard

Away from the centerline of the vehicle.

Ping

A short duration, high-frequency sound, which has a slight echo.

Pinion Shaft

The input shaft in a driving axle that is usually a part of the smaller driving or input hypoid gear of a ring and pinion gearset.

Pitch

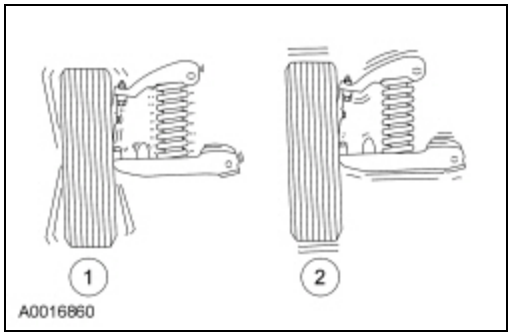
The physical quality of sound that relates to its frequency. Pitch increases as frequency increases and vice versa.

Pumping Feel

A slow, pulsing movement.

Radial/Lateral

Radial is in the plane of rotation; lateral is at 90 degrees to the plane of rotation.



Item	Description
1	Lateral runout
2	Radial runout

Rattle

A random and momentary or short duration noise.

Ring Gear

The large, circular, driven gear in a ring and pinion gearset.

Road Test

The operation of the vehicle under conditions intended to produce the concern under investigation.

Roughness

A medium-frequency vibration. A slightly higher frequency (20 to 50 Hz) than a shake. This type of vibration is usually related to drivetrain components.

Runout

Lateral runout means measuring the movement or "wobble" of a wheel or tire at the sidewall. Radial runout means measuring the out-of-round at the tread surface.

Rustling

Intermittent sound of varying frequency (100-2000 Hz), sounds similar to shuffling through leaves.

Shake

A low-frequency vibration (5-20 Hz), usually with visible component movement. Usually relates to tires, wheels, brake drums or brake discs if it is vehicle speed sensitive, or engine if it is engine speed sensitive. Also referred to as a shimmy or wobble.

Shimmy

An abnormal vibration or wobbling, felt as a side-to-side motion of the steering wheel in the driveshaft rotation. Also described as waddle.

Shudder

A low-frequency vibration that is felt through the steering wheel or seat during light brake application.

Slap

A resonance from flat surfaces, such as safety belt webbing or door trim panels.

Slip Yoke/Slip Spline

The driveshaft coupling that allows length changes to occur while the suspension articulates and while the driveshaft rotates.

Squeak

A high-pitched transient sound, similar to rubbing fingers against a clean window.

Squeal

A long-duration, high-pitched noise.

Static Balance

The equal distribution of weight around the wheel. Statically unbalanced wheel and tire assemblies can cause a bouncing action called wheel tramp. This condition will eventually cause uneven tire wear.

Tap

A light, rhythmic, or intermittent hammering sound, similar to tapping a pencil on a table edge.

Thump

A dull beat caused by 2 items striking together.

Tick

A rhythmic tap, similar to a clock noise.

Tip-In Moan

A light moaning noise heard during light vehicle acceleration, usually between 40-100 km/h (25-65 mph).

TIR

The acronym for total indicated runout is TIR.

Tire Deflection

The change in tire diameter in the area where the tire contacts the ground.

Tire Flat Spots

A condition commonly caused by letting the vehicle stand while the tires cool off. This condition can be corrected by driving the vehicle until the tires are warm. Also, irregular tire wear patterns in the tire tread resulting from wheel-locked skids.

Tire Force Vibration

A tire vibration caused by variations in the construction of the tire that is noticeable when the tire rotates against the pavement. This condition can be present on perfectly round tires because of variations in the inner tire construction. This condition can occur at wheel rotation frequency or twice rotation frequency.

Transient

A noise or vibration that is momentary, a short duration.

Two-Plane Balance

Radial and lateral balance.

Vibration

Any motion, shaking or trembling, that can be felt or seen when an object moves back and forth or up and down.

Whine

A constant, high-pitched noise. Also described as a screech.

Whistle

High-pitched noise (above 500 Hz) with a very narrow frequency band. Examples of whistle noises are a turbocharger or airflow around an antenna.

Wind Noise

Any noise caused by air movement in, out or around the vehicle.

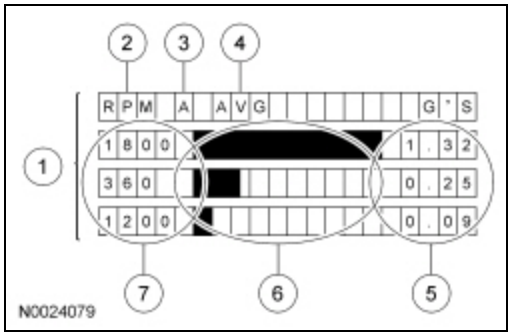
WOT

The acronym for wide open throttle is WOT.

Tools and Techniques

Vibration Analyzer (EVA)

The vibration analyzer (EVA) is a hand-held electronic scan tool which will assist in locating the source of unacceptable vibrations. The vibration sensor can be remotely mounted anywhere in the vehicle for testing purposes. The unit displays the 3 most common vibration frequencies and their corresponding amplitudes simultaneously. A bar graph provides a visual reference of the relative signal strength (amplitude) of each vibration being displayed and its relative G force. The keypad is arranged to make the EVA simple to program and use. Some of the functions include the ability to average readings as well as record, play back and freeze readings. The EVA has a strobe balancing function that can be used to detect imbalance on rotating components such as a driveshaft or engine accessories.



Item	Description
1	EVA screen
2	Frequency mode displayed in rpm or Hz
3	Active sensor input (A or B)
4	Current active mode
5	G force indicators or the strongest frequencies in descending strength of each vibration
6	Strength of each vibration
7	Frequency in rpm/Hz of each vibration

The EVA allows for a systematic collection of information that is necessary to accurately diagnose and repair NVH problems. For the best results, carry out the test as follows:

- Test drive the vehicle with the vibration sensor inside the vehicle.
- Place the sensor in the vehicle according to feel.
  - If the condition is felt through the steering wheel, the source is most likely in the front of the vehicle.
  - A vibration that is felt in the seat or floor only will most likely be found in the driveline, drive axle or rear wheels and tires.
- Record the readings. Also note when the condition begins, when it reaches maximum intensity and if it tends to diminish above/below a certain speed.
  - Frequencies should be read in the "average" mode.
  - Frequencies have a range of plus or minus 2. A reading of 10 Hz can be displayed as an 8 Hz through 12 Hz.
  - Frequencies with a reading of 0.06 Gs or less, are barely perceptible NVH levels. No corrective action is necessary.
- Place the vibration sensor on or near the suspect area outside the vehicle.
- Continue the road test, driving the vehicle at the speed the symptom occurs, and take another reading.
- Compare the readings.
  - A match in frequency indicates the problem component or area.
  - Example: A vibration is felt in the seat. Place the sensor on the console. Record the readings. Place the vibration sensor on the rear axle. Compare the readings. If the frequencies are the same, the axle is the problem component.
  - If the 2 readings are not the same frequency, then diagnose the frequency with the most significant amplitude (Gs) first.

NVH Analyzer (Vetronix)

The MTS 4000 and the MTS 4100 NVH analyzers are tools to aid in the identification and isolation of a noise, vibration or harshness concern in a vehicle. They measures noise and vibration data and compare it with data obtained from the vehicle's powertrain control module (PCM) in order to provide possible sources. The MTS 4000 and the 4100 have the following characteristics:

- Interfaces with the vehicle's computer system
- Support and store vibration data input from 1 or 2 accelerometers
- Support and store noise data input from 2 microphones
- Provide a photo-tachometer for operation of the driveshaft balancing function
- Provide a strobe output capable of driving a standard timing light
- Contain a real time clock circuit that provides time and date information which is used for tagging test data
- Have the capability to print to an external printer and interface with a PC
- Can be powered from a variety of power sources: cigarette lighter, AC power or the internal battery pack

The MTS 4000 and the 4100 NVH analyzers have 4 main operating modes. The first is for vibration diagnosis. This mode measures data from 1 or 2 accelerometers simultaneously while obtaining data from the vehicle's computer system about the operation of the vehicle. Then it does a frequency analysis on the accelerometer information and compares the vibration frequencies with the frequencies associated with various rotating components within the vehicle. The data can be presented in 4 different display modes: principle component, bar chart, frequency spectrum or waterfall. All display mode formats contain the same common elements, such as amplitude.

The second is for noise diagnosis. This mode measures noise from 1 or 2 microphones simultaneously. All noise measurements are in db's. All frequency bands used for noise measurements are the same as for the vibration measurements, up to 1000 Hz.

The third is driveshaft balancing. Driveshaft balancing is done using 1 or 2 accelerometers and a photo-tachometer. The accelerometers measure the vibrations at both ends of the driveshaft, while the photo-tachometer measures the rotation speed and position reference.

The fourth mode is the strobe. A strobe or standard timing light can be connected to an analyzer, to provide a means for measuring rotational speed. The strobe function is used for isolating the source of a vibration.

Vibrate Software®

Vibrate Software® (Rotunda tool number 215-00003) is a diagnostic aid which will assist in pinpointing the source of unacceptable vibrations. The engine's crankshaft is the point of reference for vibration diagnosis. Every rotating component will have an angular velocity that is faster, slower or the same as the engine's crankshaft. Vibrate Software® calculates the angular velocity of each component and graphically represents these velocities on a computer screen and on a printed vibration worksheet. The following steps outline how Vibrate Software® helps diagnose a vibration concern:

- Enter the vehicle information. Vibrate will do all the calculations and display a graph showing tire, driveshaft and engine vibrations.
- Print a Vibration Worksheet graph. The printed graph is to be used during the road test.
- Road test the vehicle at the speed where the vibration is most noticeable. Record the vibration frequency (rpm) and the engine rpm on the worksheet graph. The point on the graph where the vibration frequency (rpm) reading and the engine rpm reading intersect indicates the specific component group causing the concern.
    - A EVA or equivalent tool capable of measuring vibration frequency and engine rpm will be needed.
- Provide pictures of diagnostic procedures to aid in testing components.

Combination EngineEAR/ChassisEAR

An electronic listening device used to quickly identify noise and the location under the chassis while the vehicle is being road tested. The ChassisEARs can identify the noise and location of damaged/worn wheel bearings, CV joints, brakes, springs, axle bearings or driveshaft carrier bearings.

EngineEAR Basic Unit

An electronic listening device used to detect even the faintest noises, the EngineEARs can detect the noise of damaged/worn bearings in generators, coolant pumps, A/C compressors and power steering pumps. They are also used to identify noisy lifters, exhaust manifold leaks, chipped gear teeth and for detecting wind noise. The EngineEAR has a sensing tip, amplifier and headphones. The directional sensing tip is used to listen to the various components. Point the sensing tip at the suspect component and adjust the volume with the amplifier. Placing the tip in direct contact with a component will reveal structure-borne noise and vibrations, generated by or passing through, the component. Various volume levels can reveal different sounds.

Ultrasonic Leak Detector

The Ultrasonic Leak Detector is used to detect wind noises caused by leaks and gaps in areas where there is weatherstripping or other sealing material. It is also used to identify A/C leaks, vacuum leaks and evaporative emission noises. The Ultrasonic Leak Detector includes a multi-directional transmitter (operating in the ultrasonic range) and a hand-held detector. The transmitter is placed inside the vehicle. On the outside of the vehicle, the hand-held detector is used to sweep the area of the suspected leak. As the source of the leak is approached, a beeping sound is produced which increases in both speed and frequency.

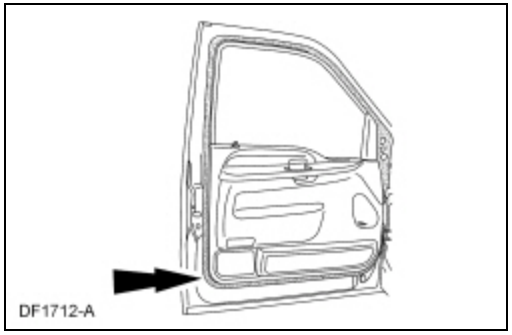
Squeak and Rattle Repair Kit

The Squeak and Rattle Repair Kit (Rotunda tool number 164-R4900) contains lubricants and self-adhesive materials that can be used to eliminate interior and exterior squeaks and rattles. The kit consists of the following materials:

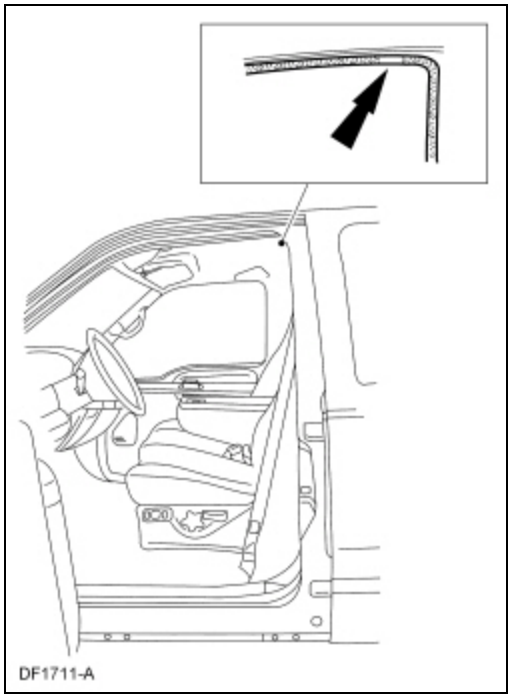
- PVC (soft foam) tape
- Urethane (hard foam) tape
- Flocked (black fuzzy) tape
- UHMW (frosted) tape
- Squeak and rattle oil tube
- Squeak and rattle grease tube

Tracing Powder

Tracing powder is used to check both the uniformity of contact and the tension of a seal against its sealing surface. These tests are usually done when a suspected air leak/noise appears to originate from the seal area or during the alignment and adjustment of a component to a weatherstrip. Tracing powder can be ordered from Crest Industries as ATR Leak Trace. Carry out the tracing powder test as follows:



- Clean the weatherstrip.
- Spray the tracing powder on the mating surface only.
- Close the door completely. Do not slam the door.
- Open the door. An imprint is made where the weatherstrip contacted the mating surface seal. Gaps or a faint imprint will show where there is poor contact with the weatherstrip.



Index Card

Place an index card or a piece of paper between the weatherstrip and the sealing surface, then close the door. Slowly withdraw the index card or paper after the door is closed and check the amount of pressure on the weatherstrip. There should be a medium amount of resistance as it is withdrawn. Continue around the entire seal area. If there is little or no resistance, this indicates insufficient contact to form a good seal. At these points, the door, the glass or the weatherstrip is out of alignment.