VIBRATION RESEARCH CORPORATION
2385 Wilshere Drive – Suite A
Jenison, Michigan U.S.A 49428
Phone 616-669-3028 Fax 616-669-5337
www.vibrationresearch.com

"Kurtosis – The Missing Dashboard Knob"

Introduction:

Many test personnel have recognized that random testing, while good, has short-comings when it comes to simulating the real-world environment. As a result, over the years, there have been many vibration testing method modifications to address these shortcomings.

I. *Problem with Present-day random testing*

In the automotive world, technicians often see that random tests do not find product faults that should show up when vibration testing. To make random testing more effective, they sometimes take the random spectrum, and increase the level according to their own internal, home-cooked formula. The level may be increased so the random peak g levels match the real world.

Present-day methods of random testing assume a Gaussian (Kurtosis = 3) mode of distribution of random data. Consequently, the majority of the accelerations seen by a product on a shaker fall near the average acceleration, with only a few of the random data points falling at extreme distances from the mean. As the following article demonstrates, some real-life data is distributed according to the traditionally used Gaussian distribution, but a lot of data does not fit Gaussian distribution. Consequently, we suggest that technicians analyze the real-life data and control the kurtosis level in their laboratory tests to match the kurtosis level of the real-life data. This is preferable because, as has been shown in recently published studies, real-life data *does not "fit"* the Gaussian distribution, but rather fits a higher kurtosis level (See: Steinwolf, A.. "Shaker simulation of random vibration with a high kurtosis value," *Journal of the IEST,* May/June 1997; 40, 3).

II. *A Solution for the Random Testing Problem*

A better method of testing products than using the Gaussian distribution of data would be to adjust the distribution of data to more closely fit the real-life data. Such a method would result in the adjustment of kurtosis. A latest modification in random testing is *a closed-loop method of Kurtosis Control*, developed by Vibration Research Corporation. This method will permit the adjustment of the kurtosis levels while *maintaining the same testing profile and spectrum attributes*.

Kurtosis is a statistical term used to describe the relative distribution of data. *Kurtosis is defined as the ratio of statistical moments.* If you have the raw zero-mean waveform data, you can compute the kurtosis in the following manner:

Kurtosis = mean(data^4) / (mean(data^2)^2). *(Equation 1)*

If your data is not zero-mean, you can subtract off the mean prior to the above calculation. Therefore, true Gaussian data will have a kurtosis value of 3.

Graphically speaking, kurtosis is a measurement of the size of the distribution's "tails". A set of data with a high kurtosis value will produce a distribution curve with higher peak value at the mean and longer "tails", or in other words, more data points at the extreme values from the mean. Compare the distributions shown for a kurtosis value of 7 with the traditional Gaussian distribution - kurtosis value of 3 (figure 1). Note how the distributions with the higher kurtosis values have more data points in the "tails" – data points that are far from the mean.

See figures 1 and 2 for comparisons of kurtosis value of 3 and 7. Interestingly, both of the data sets k=3 and k=7 produce the exact same spectrum, and rms energy.

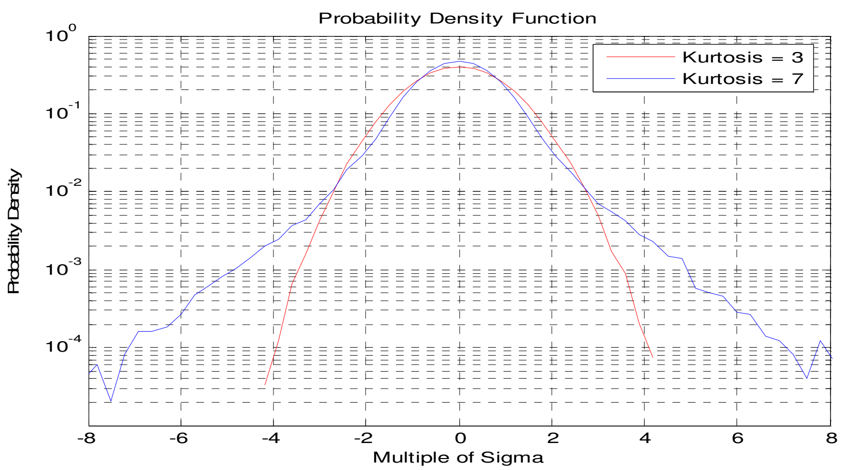

Figure 1

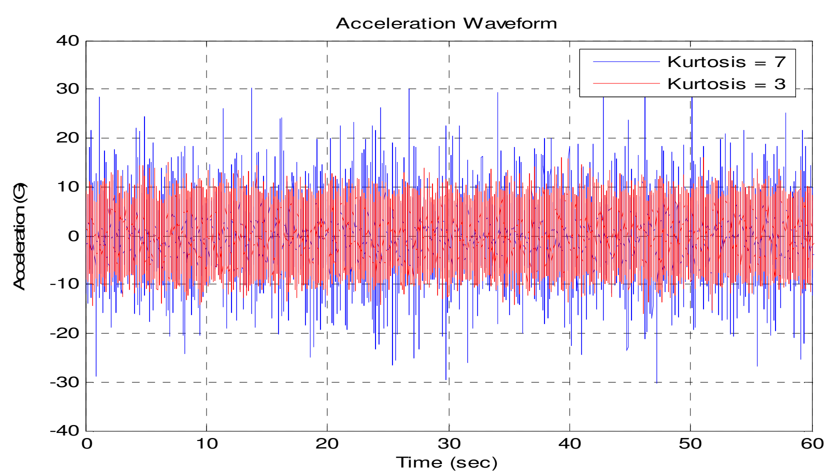

Figure 2

VIBRATION RESEARCH CORPORATION
2385 Wilshere Drive – Suite A
Jenison, Michigan U.S.A 49428
Phone 616-669-3028 Fax 616-669-5337
www.vibrationresearch.com

Report Purpose:

- To demonstrate that it is important to measure and determine the kurtosis value when collecting data to define random tests, and to demonstrate that many real-life scenarios are not always Gaussian but rather fit a higher kurtosis distribution.
- To show that Random Kurtosion® produces a closer-to-reality fit for data distribution than random testing performed with the standard Gaussian distribution.

Test Procedure:

To demonstrate the main goals of this article, two main procedures were followed:

***Procedure A*: Demonstrating the variety of distributions in real-life measured data**

A variety of real-world vibration scenarios were recorded. The kurtosis value of each test was measured. Accelerometers were mounted on various locations (windows, dashboards, armrests, steering column, PTO motor, loader frame, engine bracket etc.). The goal of this exercise was to demonstrate the variety of distributions in real-life data.

Data was collected in four different settings:

a.) 1999 Oldsmobile Bravada
b.) 2004 Cessna Skylane 182 Turbo
c.) TS110 New Holland Tractor and Celery Harvester
d.) Ground Heaters – Diesel, single cylinder generator, using Kubota engine (EA300)

***Procedure B*: Demonstrating that kurtosis distribution is more realistic and accurate than Gaussian distribution**

A number of tests that had kurtosis values greater than Gaussian distribution (k=3) were converted to random files and conducted with the traditional (Gaussian) distribution and then, using Kurtosion®, conducted with the correctly measured kurtosis value. The results were compared. The procedure for this demonstration is:

1. Two new tests (a Gaussian distribution test and a kurtosis-controlled test) were created based on the profile of the original real-life data. The real-life collected data was imported into Vibration Research Corp.'s (VRC) VibrationVIEW software in order to create a random test profile of the data.

2. We created and ran a random test using the imported profile of data with Gaussian distribution (average method with no clipping) and recorded its data, using VRC's RecorderVIEW software.

VIBRATION RESEARCH CORPORATION
2385 Wilshere Drive – Suite A
Jenison, Michigan U.S.A 49428
Phone 616-669-3028 Fax 616-669-5337
www.vibrationresearch.com

3. We then repeated the random test, now using the imported profile of data with Kurtosion®, where the kurtosis level was set at the measured level of the real-life data. The random test ran and was recorded using RecorderVIEW.

4. After running each test individually and recording its data, the new random test data ("no clipping" trial and "kurtosis" trial) was analyzed in The MathWorks' MATLAB software. Kurtosis values were calculated to confirm that they matched the required values (K=3 for Gaussian and K=real-life measured value). Acceleration waveform graphs and Probability Density Function (PDF) graphs were created. The data for the real-life data, Gaussian data, and the kurtosis-controlled data were compared *in terms of PDF and waveform.*

Test Results:

<u>Procedure A</u>: Demonstrating the variety of distributions in real-life measured data

We conducted and collected 40 different test results. Having collected data from a variety of sources with a variety of mountings, we returned to the lab. Using MATLAB and VibrationVIEW, we determined the kurtosis value of the real-life data. 58% of the data (23 of 40) had a kurtosis level greater than 3.3 (for which Kurtosion® should be a good improvement) and 43% (17 of 40) of the data had a kurtosis level greater than 3.5 (for which Kurtosion® should be an excellent improvement).

<u>Procedure B</u>: Demonstrating that kurtosis distribution is more realistic and accurate than Gaussian distribution

Once one has analyzed the collected real-life data for its kurtosis level, the more realistic way of reproducing the real-life data in the lab is to set your data distribution to the real-life kurtosis level. After the 4 step procedure discussed above was performed, two key results were observed:

1. *The Acceleration Profile or the "spectra" of the tests remained the same*, regardless of the kurtosis level. This is important because the *spectrum is the standard* when testing using the random method. Therefore, the spectrum must remain the same when the kurtosis levels change, in order to guarantee that all tests will be identical, purely from a spectrum viewpoint. Results show that the *spectrum did in fact remain the same*. See the VibrationVIEW screen shots of the graphs for a sampling of the data, Figures 3 and 4.

VIBRATION RESEARCH CORPORATION
2385 Wilshere Drive – Suite A
Jenison, Michigan U.S.A 49428
Phone 616-669-3028 Fax 616-669-5337
www.vibrationresearch.com

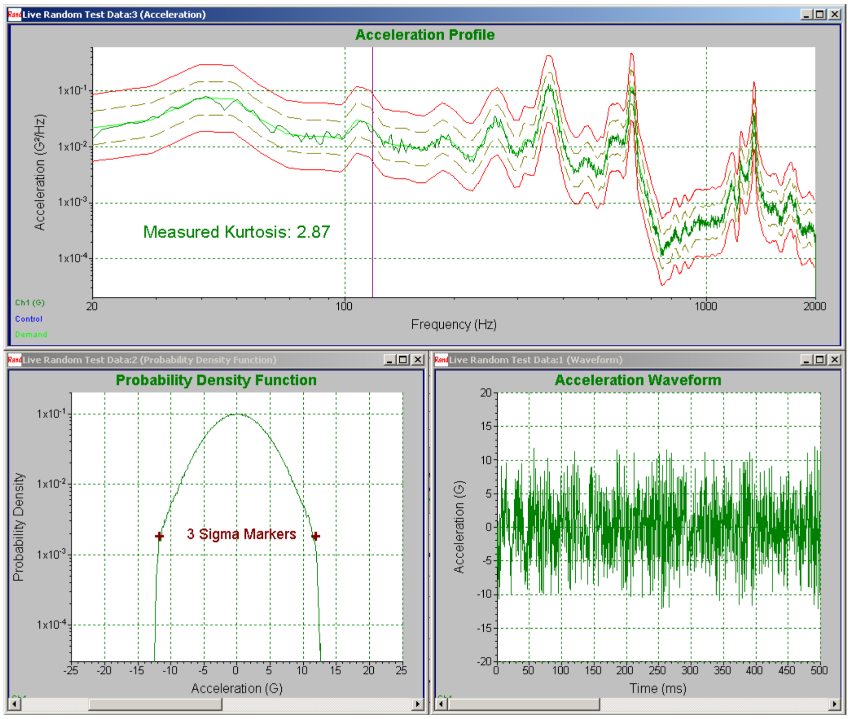

***Figure 3** – Harvester Profile Gaussian with 3 sigma clipping*

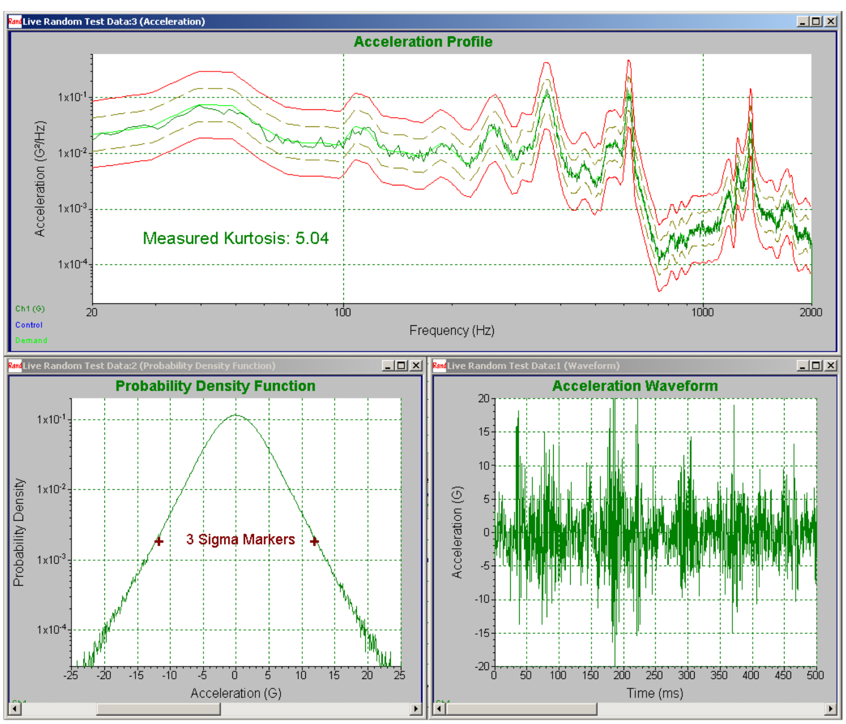

***Figure 4** – Harvester Profile Kurtosis Control set to 5*

VIBRATION RESEARCH CORPORATION
2385 Wilshere Drive – Suite A
Jenison, Michigan U.S.A 49428
Phone 616-669-3028 Fax 616-669-5337
www.vibrationresearch.com

2. *The kurtosis-controlled distribution of data more closely resembles the real-life distribution of data than the Gaussian distribution does.*

In terms of PDF:
Consider the PDF graph for a representative test result. See Figure 5.

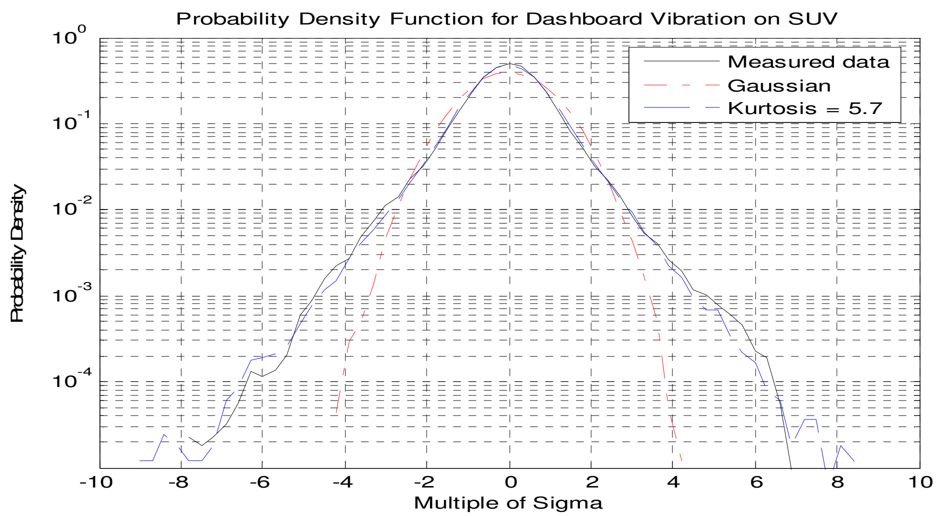

Figure 5 **–** Bravada on I-196: Dashboard mounted vibration

In terms of waveform:
The kurtosis-controlled waveform more closely resembles the real-life data's waveform than does the Gaussian waveform. The kurtosis-controlled peak accelerations are not exactly the same as the real-life data's peak accelerations but they are higher than the Gaussian method's peak accelerations. See Figure 6.

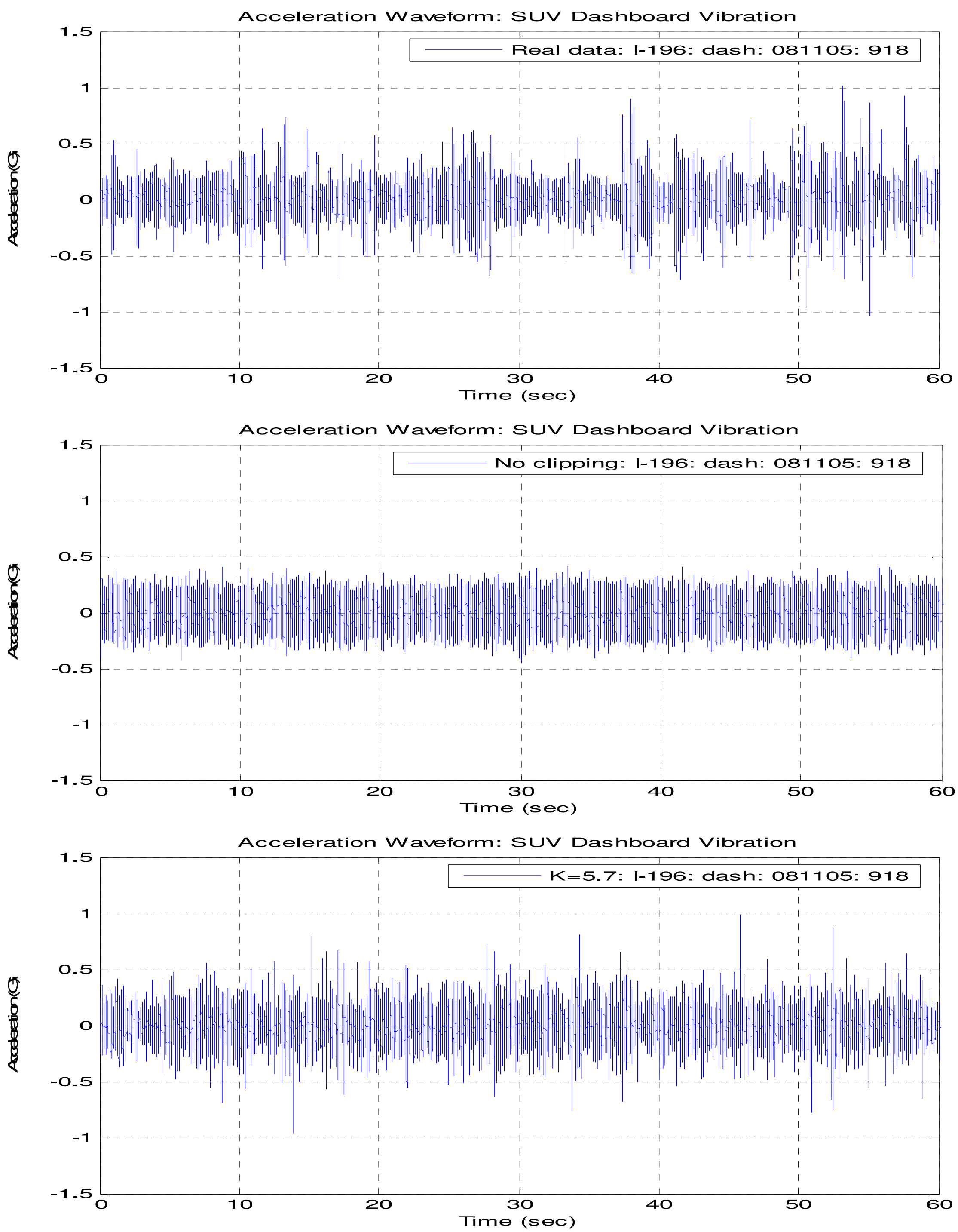

Figure 6 – Acceleration Waveforms for Bravada Dashboard vibration on I-196 (9:18 08/11/05). Measured real-life data, Gaussian (no clipping), and kurtosis-controlled (k=5.7) waveforms. Note how kurtosis-controlled waveform has peaks at +/- 1 G

(similar to original data) and how Gaussian waveform has max G levels less than +/- 0.5 G.

Conclusions:

The following can be concluded from the results:

1. Real-life data exhibits a wide variety of kurtosis values. In fact, much of real-life data is ***NOT*** Gaussian in distribution. To assume that the data distribution is always Gaussian, which is what is done in present-day methods of testing, is to be unrealistic in testing. **Therefore, to increase the realistic nature of testing, we suggest that technicians determine the kurtosis value of a sample of data and then match that kurtosis value in their laboratory tests.** The kurtosis determination can be easily calculated using Equation 1, and can be automatically calculated using VRC's Kurtosion® software.

2. In real-life scenarios where the kurtosis value is greater than Gaussian (K = 3), Kurtosion® is an excellent method to use to bring the laboratory test closer to reality. This was demonstrated with a number of test examples. When Kurtosion® software is used the data distribution very closely matches the data distribution of the real-life test (Figure 5) and the acceleration waveform maximum peaks are much closer to the peaks in the real-life data than the peaks of Gaussian distribution (Figure 6), all the while maintaining the exact same test specifications (test profiles) (Figures 3 and 4). **When test technicians find real-life data samples that have kurtosis values greater than Gaussian distribution, Kurtosion® software can make their tests more closely resemble the real world.**