EDITORIAL

From Guess to Gospel – The Curious History of Floor Vibration Criteria

***Eric E. Ungar**, Contributing Editor*

In the 1980s, when many "wafer fabs" (semiconductor micro-electronics manufacturing facilities) were being built, there was much justified concern regarding the vibration sensitivities of the equipment housed in these facilities. My colleague, Colin Gordon (then at Bolt Beranek and Newman and later at his own consulting firm), perceived the need for a way to define the vibration limits to which these facilities should be designed.

As a result, he came up as an initial guess with a series of curves like those shown in Figure 1, which are shifted by successive factors of two from the curve labeled "Operating Theater," which corresponds to a most sensitive standing or sitting person's threshold of perception of vertical floor vibrations.

There is no reason for the vibration sensitivities of instruments or micro-electronics equipment to be similar to those related to human perception. Although we found some items of equipment whose sensitivities, as delineated by the equipment's suppliers, corresponded to the constant-velocity portions of the Figure 1 curves, we observed that the sensitivities of most equipment items of interest follow vastly different curves. Nevertheless, the set of curves – originally dubbed the "BBN criteria" and eventually renamed VC (vibration criterion) curves – found wide use, possibly because nothing better was available and because they provided a simple means for communicating the vibration limits desired in a given installation.

Hal Amick of Colin Gordon Associates observed that some items of sensitive equipment were mounted on soft isolators, which led to resonances at low frequencies. Correspondingly, the vibrations of floors supporting this equipment should be limited more severely than implied by the VC curves. Therefore the low-frequency "hook" was eliminated from the lowest VC curves, and the constant velocity portion was extended down to 1 Hz, as shown in Figure 2.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) also in essence copied the VC curves, extended the curves related to human perception to lower frequencies, and kept the extended horizontal portions of the lowest VC curves, as shown in Figure 3.

Curiously, the curves published in some of the earlier ASHRAE handbooks had letter designations beginning with "A" corresponding to 125 micro-inches per second (3.1 micro-meters per second) and ascending up the alphabet for increasing velocities. This is in contrast to the VC

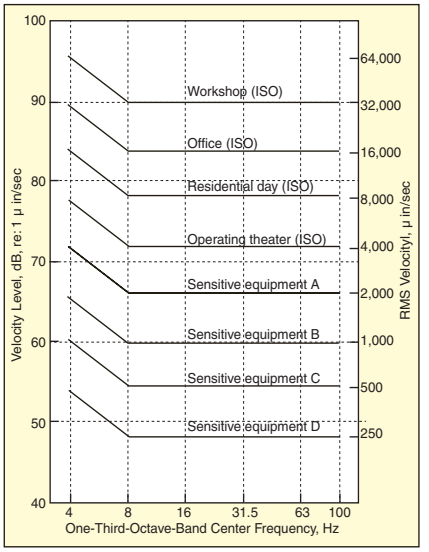

Figure 1. Criteria originally suggested for micro-electronics equipment.

designations, which begin with "A" corresponding to 2000 micro-inches per second (50 micro-meters per second) and ascending up the alphabet for decreasing velocities. This dichotomy caused a great deal of confusion. Since, for example, ASHRAE-D corresponded to VC-B, it was not clear what a client meant when he required that his facility be "designed to D." Fortunately, ASHRAE got on the bandwagon and eventually changed its letter designations to match the VC curves.

By now the VC curves, sometimes with variations, have found their way into numerous specifications and design guides and now are considered essentially as "the Gospel." And the circle has closed to the extent that some suppliers of sensitive equipment have chosen to prescribe the floor vibration limits for their equipment in terms of the VC curves, rather than in terms of their more complex measurement-determined sensitivity curves.

Some Background

Figure 1 is adapted from "Cost-effective design of practically vibration-free facilities," E. E. Ungar and C. G. Gordon, *Proceedings of Symposium on Noise and Vibration Measurement: Prediction and Mitigation, Environmental Engineering Division of American Society of Civil Engineers*. May 1986.

Vibration limits for many items of micro-electronics equipment are noted in "Vibration challenges in microelectronics manufacturing", E. E. Ungar and C. G. Gordon Shock and Vibration Bulletin 53 (1), May 1983.

Figure 2 is adapted from "Evolving Crite-

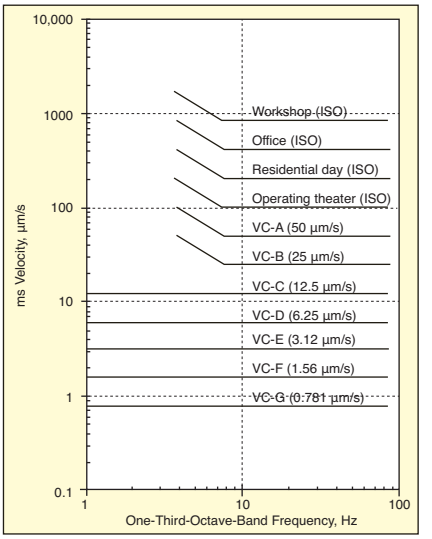

Figure 2. Criterion curves with extensions to lower frequencies.

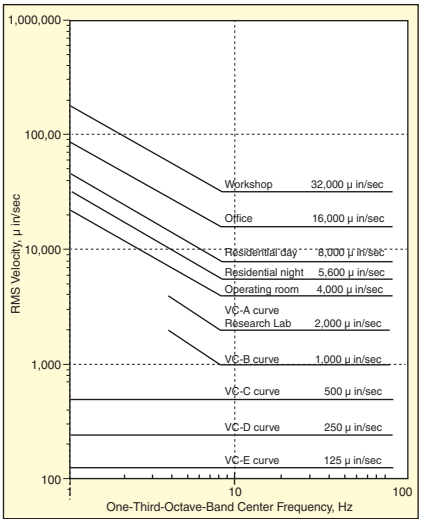

Figure 3. ASHRAE criteria.

ria for Research Facilities 1 – Vibration," C. H. Amick, M. Gendreau, T. Bush, and C. G. Gordon," *SPIE Conference 5933. Buildings for Nanoscale Research and Beyond,"* Aug 2005. This publication also discusses the applicability of the VC criteria to various types of instrumentation.

ASHRAE curves with lettering opposed to that of the VC curve appear in the 2004 ASHRAE Handbook, for example. Figure 3 is adapted from the 2012 ASHRAE Handbook.

Human perception and sensitivity criteria appear in "Guide to the Evaluation of Human Exposure to Vibration in Buildings" American National Standard, ANSI S3.29, 1983. SV

The author can be contacted at: eungar@acentech.com.