Peak Particle Velocity vs. the Richter Scale

by Wes Bender

Several times when I have been going over a seismograph record with someone who is not familiar with blasting (let alone blast vibration), I have been asked how the peak particle velocity levels shown on the seismograph records compare to the numbers on the Richter scale. This may seem like a reasonable question; however, it shows that the individual asking it either doesn't understand what the Richter Scale is or else they do not understand the difference between magnitude and intensity.

The Richter Scale was developed by Dr. Charles Richter (with assistance from others) at Cal tech and is a scale that represents the overall magnitude of an earthquake. Although the ground motion from the earthquake has different intensities at different locations (just as in blasting), the total size of the earthquake is determined and is expressed by a number on the scale.

While a number on the Richter Scale represents the total **magnitude** of an earth-motion event, the readings on a seismograph indicate the **intensity** of ground motion at a given location. The magnitude of a particular event will remain the same, but the intensity of vibration will vary depending upon how far from the epicenter you are taking readings. In other words, there would be no practical way that you could relate your seismograph readings (taken at one location) to the Richter Scale.

We measure blast vibration intensities in terms of inches per second or millimeters per second of particle velocity. Earthquake intensities (as opposed to earthquake magnitudes) are assigned a number on the Modified Mercalli Scale, a scale that relates ground motion intensity to the apparent effect of the motion at that particular location. In greatly simplified form, the scale ranges from MM I, which is only detectable by very sensitive instruments, to MM XII which represents total destruction of structures. One cannot readily assign particle velocities to the twelve different MM levels and it would not be technically correct to do so.

There is such a great difference in the characteristics between blast vibration and earthquake motion that it is not feasible to try to relate the two in any logical manner. The frequency of blast vibration could range from several hertz (at greater distances) to 700 to 1000 hertz or higher (in close proximity to the blast). Earthquake frequencies are so low that they are not normally measured in hertz but rather in the number of seconds for a full cycle or period. You might see rather high acceleration levels from a blast, but the displacements would be so low that they would not cause damage. On the other hand, an earthquake may cause damage at rather low acceleration levels because the displacements could be quite high.

In California (and possibly other states as well), bridges and other highway structures are designed to survive specific earthquake acceleration levels. These could be quite low, on the order of 2 to 4 Gs or so. You can see why a structural engineer might become concerned when you tell him that you expect acceleration levels from a blast to reach 4 or 5 Gs, measured on the ground at the base of his structure. Unless he can also understand that the displacements are only going to be on the order of a few ten thousandths of an inch and will not damage the structure, it isn't likely that you will be allowed to blast.

While we can't relate your seismograph reading to Dr. Richter's scale, we might try to relate the size of the entire blast to it. First we must disregard some of the differences between blasts and earthquakes such as energy release of the explosive, spatial separation of charges, frequency, time duration of energy release, depth to the source of energy, etc.

Let's see how many pounds of explosive it would take to theoretically reach various Richter numbers. Several years ago Dr. Doug Anderson presented a paper at the ISEE on the topic. Doug used information developed for nuclear testing and fully explained his calculations in his paper, hence (if we accept his cautionary notes and assumptions) we can use his calculations to reach an approximate magnitude based upon explosives weight. He recognized that the Richter magnitude would only relate to the total blast if all explosives were detonated simultaneously. We don't do that very often. He also noted that it would not strictly relate to the charge weight per delay (unless there was an unusually large delay between charges making each an individual blast, which we also don't normally do.) The actual magnitude number would then fall somewhere between that calculated for the entire blast and that calculated for the largest charge weight per delay.

For purposes of the following table, we will assume that we are initiating one charge of the weight indicated. This will result in the highest possible Richter magnitude for the event. If you decide to break the event up into delays and calculate another Richter number for the largest charge weight per delay, as stated above, the actual Richter magnitude for the event would fall between the two. Dr. Anderson made it abundantly clear that these were going to be very rough approximations, so don't try to take them to court with you!

Magnitude	Pounds of Explosive
5	2,000,000,000
4	200,000,000
3	20,000,000
2	2,000,000
1	200,000
0	20,000
-1	2,000
-2	200
-3	20
-4	2

If you wish to calculate your own magnitude numbers using Dr Anderson's assumptions, the formula he used is as follows:

$$M_{ce} = (\log w) -1$$

where M_{ce} is the Magnitude for chemical explosions, and
w is the explosive weight in tons.

As you can see, it takes a lot of explosive energy to achieve a magnitude similar to that of an earthquake. As Doug points out in his paper, if the smallest earthquakes that can be felt are about magnitude 2 or 3, how come people are complaining about your blasts that may only have a few pounds loaded? Congratulations. You have just discovered the difference between **magnitude** and **intensity**. While the magnitude of your blast may be quite small, where you are locating it in relation to their residence makes the difference. The vibration intensities that you record with your seismograph next to their foundation is much more important than the overall blast size......but then I guess you knew that all along, anyway.