# Impulse Noise Hazard – What do we know about it?

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## INTRODUCTION

There is no definition for impulse noise. It is generally accepted that its duration is of less than 0.5s and that is separated from other noises by more that 0.5s. If generated by collision of material bodies, it is called impact noise. Otherwise it can be generated by a sudden expansion/contraction of the air due to a spark or an explosion.

Although impulse noises are of short rise time, the decay time is a function of the acoustical environment: if in the open or in location with highly absorbent boundaries, it is also very short. However, in a reverberant location, such as most enclosed workplaces are, the decay time can be long enough as to blend with subsequent impulses in such a way that they are not separated in time and, as a result, they loose the impulse characteristic.

## HEARING AND IMPULSE NOISE

To describe a continuous noise, it is sufficient to know its sound level, duration and frequency content. This is not the case with the impulse noise, whose characteristics are many more: rise time, decay time, peak value, pulse duration, repetition rate, number of impulses and kurtosis. However, historically, for the assessment of the hearing hazard only the peak value, some measure of duration, and the number of impulses have been considered as of importance.

That is why attempts to set Damage Risk Criteria (DRC) for impulse noise to avoid damage to the hearing have taken into account only those characteristics. The first one was prepared by the Committee on Hearing, Bioacoustics and Biomechanics (CHABA) in 1968. It was done for noise from gunfire and the limits were set in terms of duration of the impulse, peak value and number of impulses. Limits were derived from studies where $TTS_2$ (temporary threshold shift 2 min after the end of the exposure) measurements where performed on subjects

In 1972 many studies done mainly in UK following epidemiological surveys, came to the conclusion that, when integrating the sound level using 3 dB exchange rate, there should be no difference between the different types of noises, whether they are continuous, interrupted or impulsive. By accepting this principle, known as the Equal Energy Principle, the measurement as well the assessment of the noise of any kind becomes a very simple exercise: just use an sound integrating device, such as a dosimeter or a dosimeter and if the result is lower than the accepted limit, then there is no hazard to the hearing of the exposed person.

However, further research, especially with very high noise levels, had shown that the linear relation between noise exposure levels and hearing loss, as stated by the Equal Energy Principle is not valid for high noise levels, such are those found in the military environment. The linearity exists only up to levels around 140 dBA. It was found also, that the damage to the hear cells, that is purely metabolic becomes mechanical above those levels. That is when the concept of "critical level" was introduced, as been the level above which, the mechanical damage starts. In other words, it was confirmed that for those levels, the peak pressure level is not a sufficient indicator of auditory hazard. However, energy alone is not a sufficient indicator either. As an example, it was found that the same energy applied to the ear could be more or less damaging, depending of its frequency content. Very high levels generated by large gun fire resulted in lower $TTS_2$ than gun fire from small arms that generate lower sound levels. This fact could not be explained even when the measured noise was A-weighted.

## AHAAH

The auditory Hazard Assessment Algorithm for Human (AHAAH) was created by Price and Kalb in 1995 and was improved since. It is the first attempt to explain the above-mentioned abnormalities and, at the same time, to provide a tool that could allow for the assessment of the hearing hazard from impulse noise of levels in excess of 150 dBPeak. To do so, the authors created a mathematical model of the entire ear – external, middle and inner including muscles and bones. In the model the ultimate receptor of the noise, the basilar membrane, was divided into 23 locations. When the impulse is entered in the model, the basilar membrane oscillates. For each of the 23 locations the upward flexes are tracked, their amplitude in microns is squared and the sum maintained for each location. The units are called Auditory Hazard Units (AHUs) that is the sum of microns squared.

The model operates on a PC in WINDOWS environment. The waveform of the signal to be assessed is entered in the program as an ASCII file. The output is the number of AHU units. 500 AHUs are the upper limit for a single exposure, with more than 500 AHUs producing an immediate permanent hearing loss.

The AHAAH method has been tested in animals and validated in humans. It has proven to be correct in 95% of the tests with protected hearing and 96% of the instances for all tests.

In an evaluation performed in 2001, the American Institute of Biological Sciences concluded that the method is basically sound for frequencies < 5KHz, not so for higher frequencies1. They also found that the program is not easy to run from the point of view that is not easy to change variables and algorithms. However, as a bottom line they concluded that for the time being it is he best available instrument but it has to be improved.

Presently the method is used by the Society of Automotive

Engineers (SAE) Committee on Inflatable Restraints for the evaluation of airbag design and safety. Also, the US Army Center for Health Promotion and Preventive Medicine (USA-CHPPM) is using it for evaluating hazard to unprotected ears and is working to produce a version that includes hearing protection. Finally, the US Army military standard MIL-STD-1474D, that includes the AHAAH method, is presently sent for comments to the interested bodies.

## WHAT ABOUT THE INDUSTRY? (See Footnote 1)

Noise levels in the industry are usually much lower than those from military operations, rarely above 120 dBA Peak. Therefore, the Equal Energy Principle applies with no restrictions. Therefore an integrating instrument such as an Integrating Sound Level Meter or a dosimeter will process the impulse as well as the continuous noise existing in the premises. As a consequence, the final reading on the instrument will provide the information on the total of the acoustical energy, independently of the duration, shape and number of impulses.

Most occupational hygiene standards and regulations worldwide stipulate that no unprotected ear should be exposed to sound levels in excess of 140 dBAPeak or dBCPeak. Using the well known formula for the calculation of noise exposure as a function of the sound level and duration:

$$L_{ex} = 85 - 10Log(X/28,800)$$

Where Lex is the resulting exposure and X, the exposure duration in seconds, it can be found that after only 1-second exposure to 130 dB the exposed person will reach the maximum allowed 85 dB. In other words using an integrating instrument just one impulse of 130 dBA (well below the critical level) will result in a reading higher than 85 dBA, indicating overexposure.

## CONCLUSIONS

From the above it can be concluded that:

a) For impulse noises below the critical level, (accepted to be higher than 140 dBPeak), commonly found in the industry, the Equal Energy Principle is valid and any integrating measuring instrument can be used to assess the hearing hazard in the workplace. Keeping Lex at or below the 85 dBA limit should ensure a safe environment where hearing of the exposed personnel is not compromised.

b) No unprotected ears should be exposed to noise with peak levels higher than 140 dB. Special care should be taken when dealing with military environment. There, a thorough study should be performed to assess the noise level of the protected ear, eventually using the AHAAH Method.

Footnote 1

"The panel opined that the middle ear of the model might not be good for frequencies >5kHz; but they cited no evidence that the model wasn't accurate there. To the contrary, the model reproduced Loeb and Fletcher's data for spark gap noise exposures that peaked at 3 kHz and higher" – R. Price – Personal Communication.