

A DRC-based Analysis of the Auditory Hazard from Exposure to Impact Noises Generated by Carpentry Tools and Tasks

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Summary: The German, French, Dutch, and an adjusted CHABA Damage Risk Criteria (DRC) were used to assess the potential for carpentry-based impact noises to present an auditory hazard to construction workers. The peak sound pressure level, duration, and A-weighted energy of common carpentry task-related impacts were determined by digitizing the events and then processing the waveforms using two impulse noise analysis programs. The maximum number of allowable exposures was calculated for each event based on the levels set by the DRCs and then compared to published and observed productivity rates. The results showed that among the four DRCs, the German was the least protective, finding only five of the twelve exposures to be hazardous, and the French (seven), Dutch (eleven), and adjusted CHABA (twelve) incrementally more protective.

INTRODUCTION

Research conducted over the past thirty-five years suggests that exposure to high intensity impulsive type sounds, such as the impact noises generated on construction sites, presents a serious auditory hazard. In the United States, permissible noise exposure levels for construction workers are set by the Occupational Safety and Health Administration's Title 29, Part 1926, Subpart D, Section 52 standard (OSHA) (1). This standard makes provisions for continuous noise exposures up to 115 dBA, and for exposure to single impulse or impact noise events with peak sound pressure levels (L_{pp}) greater than 140 dB. There are no provisions for impact sounds less than 140 dB other than to integrate them into the overall A-weighted sound exposures for an entire working day, which may not accurately reflect the actual hazard to hearing. Preliminary research showed common hammering tasks as well as tasks involving compressed air nailguns produced peak sound pressure levels at the operator's ear in the 120 to 140 dB range. The research presented here represents an effort to determine if there is a potential auditory hazard from exposure to these impact noises using an adjusted version (2) of the original damage risk criteria (DRC) developed by the U.S. National Academy of Sciences, National Research Council's Committee on Hearing, Bioacoustics and Biomechanics (CHABA), Working Groups 46 (3) and 57(4), upon which the OSHA limit is loosely based, and the German (5), Dutch (6), and French (7) DRCs.

METHOD

Impact noise data were collected and analyzed in the following four steps:

Step 1. Selection of Impacts: A variety of carpentry based tasks utilizing compressed air nailguns and hammers were selected for analysis. These tasks were chosen as they are representative of a majority of carpentry based tasks that create impact noises on construction sites.

Step 2. Data Collection: The nailgun measurements were made in the field, while the hammering tasks were made in a laboratory environment. All measurements were made using a LeCroy 6810 digitizer and Waveform Catalyst v.3.0 software to capture and display the waveform of each impulse. Measurement's were made at the operator's ear with the microphone at grazing

incidence to the wavefront. A Brüel and Kjær model 4134 1/2" (13 mm) diameter condenser microphone with a model 2639 preamplifier connected to a Brüel and Kjær model 2804 power supply was used. A calibration signal was recorded before and after all measurements using a Brüel and Kjær Type 4228 pistonphone producing a 124 dB rms sine wave (127 dB peak) at 250 Hz. A sampling rate of 100 kHz was used for most of the measurements to avoid aliasing and provide high resolution of the waveform. The nailgun impacts, which have significantly more energy than other impacts, were digitized at a sampling rate of 50 kHz due to the limited computer storage space available at the time.

Step 3. Waveform Processing/Determining Parameter Values: To determine the limiting number of exposures for a given impact noise based on the four DRCs, the value of the parameters used in the DRCs were found for each recorded impact. The only parameter required by the French DRC is the A-weighted energy. The L_{pp} of the impulse must be known for the CHABA, German, and Dutch DRCs, as well as the duration (CHABA: B-duration, German: C-duration, and Dutch: D-duration). To determine these values, the output from the Catalyst software was run through two waveform analysis programs (8). Readers are directed to Smoorenburg (9) for a description of the B-, C-, and D-durations.

Step 4. Hazard Prediction: Once the parameter values were determined, the maximum number of allowable impulses in an eight hour exposure, based on the requirements of each DRC, was computed for each of the recorded impacts. This was done by reducing the criteria curves for each DRC into simple equations with the maximum number of allowable impulses (N) remaining as the only unknown, and then solving for N (see Table 1) (8). The exception to this is the adjusted CHABA DRC, which utilizes a "best-fit" type criteria curve and therefore could not be reduced to a simple equation. In this case, N was derived by plotting the parameter values on the CHABA criteria curves (2).

The likelihood of exceeding the exposure limits imposed by each DRC was determined by comparing the limit number for a particular task to the number of impacts a worker is likely to be exposed to after eight hours of performing that task. This number was determined through the use of two references that publish productivity rates of various construction processes and through observations made during construction site visits.

RESULTS

The results from the comparison of the maximum number of impact exposures for the 12 tasks allowed by each DRC and the predicted number of impacts in an eight hour exposure is presented in Table 1. Where the predicted number of impacts exceeds a DRC limit, a plus (+) symbol is marked next to the DRC limit. Where the predicted number of impacts does not exceed the DRC limit, a minus (-) symbol is marked.

TABLE 1: Equations used in calculating maximum number of allowable impulses for three of the four DRCs.

DRC	Equations to Solve for Maximum Allowable Impacts in an 8h Exposure
German (Pfander <i>et al.</i> , 1980)	$N = 10^{((165 - 10 \log C - L_{pp})/10)}$; where C = C-duration (in msec)
Dutch (Smoorenburg, 1982)	$N = 10^{(-(L_{pp}-136)/10) - \log(D/1000)}$; where D = D-duration (in msec)
French (French Legislation, 1975)	$N = 8.91/E_{A-weighted}$; where $E_{A-weighted}$ is the A-weighted energy (in J/m ²)

TABLE 2: Comparison of Predicted Number of Impacts and DRC Limits. Plus (+) sign indicates potential hazard.

Task Description	L _{pp} (dB)	Predicted # of impacts	Maximum Allowable Impacts in an 8-Hour Exposure							
			CHABA	+/-	German	+/-	Dutch	+/-	French	+/-
NAILGUN1	134	1,900 ¹	175	+	2,284	-	31	+	1,157	+
NAILGUN2	125	1,900 ¹	450	+	5,076	-	249	+	3,713	-
NAILGUN3	126	1,900 ¹	450	+	2,904	-	364	+	1,713	+
NAILGUN4	135	>10,000 ²	300	+	1,981	+	1024	+	938	+
NAILGUN5	122	>10,000 ³	600	+	2,564	+	455	+	1,591	+
HAMPLYPE	126	>5,000 ⁴	340	+	1,850	+	336	+	1,172	+
HAMPLYP01	122	≈5,500 ⁴	1,050	+	12,342	-	1,988	+	11,138	-
HAMPLYP02	127	≈1,750 ^{4,5}	430	+	1,653	+	480	+	1,747	+
HAM2X4PE	129	≈1,900 ⁶	500	+	10,638	-	3,182	-	4,950	-
HAMNRFE	131	See Note 7	250	+	442	+	84	+	450	+
HAMNRPE	129	See Note 7	450	+	5,080	-	737	+	2,285	-
HAMNRPO	132	See Note 7	450	+	2,103	-	687	+	1,392	-

Data Descriptions (unless otherwise indicated, measurements were made with the microphone at the operator's ear):

- NAILGUN1 - Installation of oriented strand board (OSB) sheathing on the exterior of a residential building using a compressed air coil nailer loaded with 8d nails.
- NAILGUN2 - Same as NAILGUN1, except microphone was located 1 m to side of operator (to simulate effects on co-worker holding the sheathing).
- NAILGUN3 - Same as NAILGUN1, except using a framing nailer loaded with 12d nails.
- NAILGUN4 - Installation of plywood decking on 3rd floor of a residential building using a coil nailer loaded with 8d nails.
- NAILGUN5 - Measurement taken at ear height on deck below where the NAILGUN4 event was taking place.
- HAMPLYPE - Hammering an 8d nail into 13mm (1/2") plywood on 40mm x 80mm (1-1/2" x 3-1/2") framing lumber (2x4s) in a partially enclosed environment in which two of the six sides were open to the outdoors.
- HAMPLYP01 - Same as HAMPLYPE1, except done in a partially outdoor environment in which 4 of the six sides were open to the outdoors.
- HAMPLYP02 - Same as HAMPLYP01, except the strike on the nail actually finished the nail, meaning much of the impact was the hammer hitting the plywood.
- HAM2X4PE - Hammering a 2x4 stud into a 2x4 sill plate using 10d nails in the partially enclosed environment.
- HAMNRFE - Removing an 8d nail from plywood attached to 2x4 studs by striking a steel nail remover (cat's claw) with a hammer in a fully enclosed room (laboratory).
- HAMNRPE - Same as HAMNRFE, except done in the partially enclosed environment.
- HAMNRPO - Same as HAMNRFE, except in done in the partially outdoor environment.

Notes:

1. Based on sheathing productivity rates (10).
2. Based on witnessed rate of flooring installation of 500 nails (impacts) in five minutes. A predicted daily exposure of 10,000 impacts is conservative.
3. Assumes worker below flooring installer present for at least several hours.
4. Based on plywood subflooring installation productivity rates (11).
5. Assumes one or two "finishing" hits per nail.
6. Based on interior partition installation productivity rates (11).
7. This number varies greatly. It is possible that in the course of removing several sheets of plywood decking or sheathing, as many as 500 - 1,000 impacts could occur in an 8 hour day. This is not likely to be a daily occurrence, however.

CONCLUSIONS

The results of this study suggest that the majority of the impact type noises to which carpentry workers are exposed present a potential auditory hazard. It is interesting that the adjusted CHABA DRC found all twelve exposures hazardous, while the OSHA limit of 140 dB, which is based on the original CHABA research, was not exceeded by any of the impacts. Of course, it is not possible to say with complete certainty that any of these impact exposures would be hazardous. There are far too many deficiencies in the DRCs to make such a claim. However, the deficiencies in the DRCs tend to err on the side of being less protective than perhaps they should be, suggesting that the impacts studied here are possibly more hazardous than the DRCs have predicted.

It is clear from the results of this study that some level of protection from construction site impact noise is needed. The simplest solution is to make the use of hearing protection mandatory on construction sites, similar to the manner in which hard hats are mandatory, if not for all tasks, at least for those tasks or occupations that present auditory hazards. The determination of tasks that require hearing protection would require wide-scale site noise surveys, as well as an extensive review of noise levels published in the literature. Ideally, research in this area will lead to a better understanding of the more hazardous tasks and the scale of hearing protection required.

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