Regulating Occupational Exposure to Noise - A Review
(Revised September 1982)

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Abstract

A brief historical background to occupational noise regulations is provided with a description of the "dose-relationships" used today. A summary of the regulations (existing and proposed) in Canada is presented outlining noise limits and various alternative noise protection measures. The benefits of hearing conservation programmes and education, and the limitations of present regulations are discussed. Methods of assessment of compensation for occupational noise-induced hearing loss are also described.

Sommaire

Cet article est un résumé historique de la réglementation concernant l'exposition au bruit en milieu de travail et description des relations dose-effet utilisées aujourd'hui. Un sommaire des règlements canadiens (en vigueur et proposés) est présenté incluant les niveaux sonores limites ainsi que diverses mesures possibles de protection contre le bruit. Il est également question des avantages que présentent les programmes de protection de l'ouïe et d'éducation en la matière, et des limites des règlements actuels. On trouve en outre une description des méthodes de calcul des indemnités à verser en cas de troubles de l'audition résultant de l'exposition au bruit en milieu de travail.

1. Background

1.1 History

Loss of hearing from exposure to industrial noise was recognized as early as 1831 by J. Fasbrooke[17]. Since that time numerous surveys of the hearing of industrial workers have been made both in Europe and North America. Early investigators felt that a single value for the noise level at all frequencies would be adequate for defining a safe level. However, by the 1950's it was clear that proposed noise limits should consider other physical

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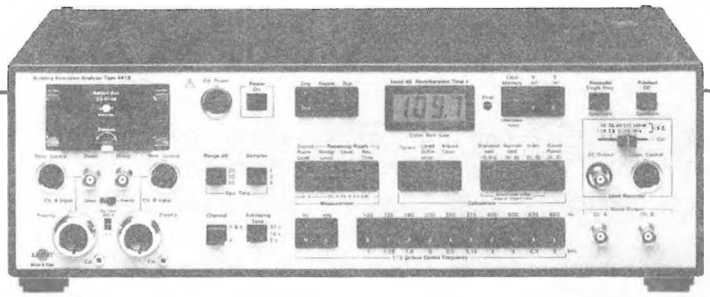

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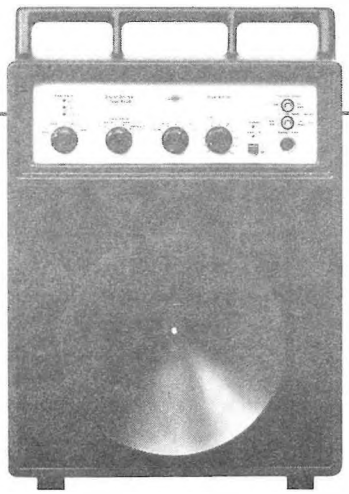

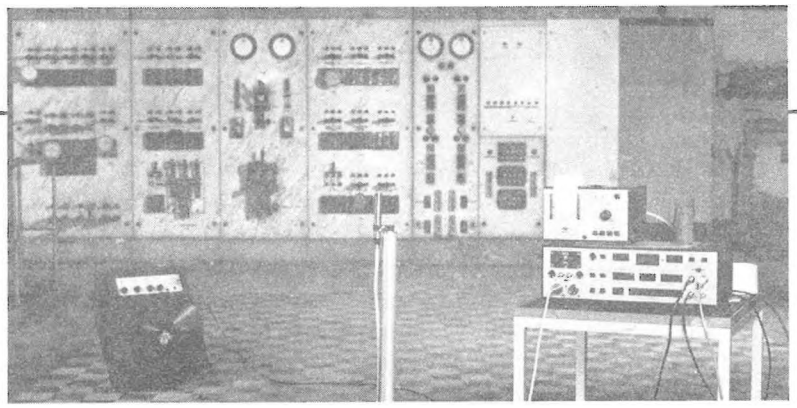

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00				No Option Calculations		
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12	Normalized Level Difference + Index		DIN 52210	LSM (Luftschallschutzmaß)		100–3150
12	Normalized Impact Level + Index		DIN 52210	TSM (Trittschallschutzmaß)		100–3150
20	Receiving Room and Background Levels	*	ISO 140	Removal of Backgr. Level Correction		100–8000
21	Receiving Room and Background Levels	*	ISO 140	Background Level Correction		100–8000
22	Any Measurement	*	Circ. 29/6/72	Octave Conversion of all Measurements		100–8000
22	Any Calculated Level Difference	*	Circ. 29/6/72	D dB(A) (Octaves, Pink Source)		100–5000
22	Any Calculated Level	*	Circ. 29/6/72	dB(A) Calculation (Octaves)		100–5000
23	Any Measured or Calculated Level	*	NF S 31–052	dB(A) Calculation		100–5000
23	Any Level Difference	*	NF S 31–051	R dB(A) (Pink Source)		100–5000
30	Receiving Room and Background Levels	*	ISO 140	Removal of Backgr. Level Correction		100–8000
31	Receiving Room and Background Levels	*	ISO 140	Background Level Correction		100–8000
32	Any Measurement	*		Octave Conversion of all Measurements		100–8000
32	Standardized Level Difference + Index		NEN 1070	I(iu) (Octaves)		100–2500
32	Standardized Impact Level + Index		NEN 1070	I(co) (Octaves)		100–2500
40	Receiving Room and Background Levels	*	ASTM E492–73T	Removal of Backgr. Level Correction		100–8000
41	Receiving Room and Background Levels	*	ASTM E492–73T	Background Level Correction		100–8000
42	Level Difference + Index		ANSI E336–77	NIC (Noise Insulation Class)	3)	125–4000
42	Standardized Level Difference + Index		ANSI E336–77	NNIC (Norm. Noise Insulation Class)	3)	125–4000
42	Normalized Level Difference + Index		ANSI E336–77	FSTC, STC (Sound Transmission Class)	3)	125–4000
42	Normalized Impact Level + Index		ASTM E492–73T	IIC (Impact Insulation Class)	3)	100–3150
50	Receiving Room and Background Levels	*	ISO 140	Removal of Backgr. Level Correction		100–8000
51	Receiving Room and Background Levels	*	ISO 140	Background Level Correction		100–8000
52	Any Measurement	*		Octave Conversion (1/3 Octave Step)		100–8000
52	Normalized Level Difference + Index		ÖNORM S 5100	LSM (Luftschallschutzmaß)		100–3150
52	Normalized Impact Level + Index		ÖNORM S 5100	TSM (Oct. Conversion, 1/3 Oct. Step)		100–4000
90	Receiving Room and Background Levels	*	ISO 140	Removal of Backgr. Level Correction		100–8000
91	Receiving Room and Background Levels	*	ISO 140	Background Level Correction		100–8000
92	Any Measurement	*		Octave Conversion of all Measurements		100–8000
93	Any Level	*		dB(A) Calculation		100–8000
94	Any Level or Level Difference	*		Rounding to nearest dB		100–8000
95	Any Measurement			'Run': Same Frequency		100–8000
96	Any Measurement			As above, 15 Measurements averaged		100–8000

Notes:
1) * means: Press 'Option' to perform Calculation.
2) For each group, Measurement in 'Run' stops after the underlined frequency, if Program Switch No.5 is Closed.
3) Program Switch No.1 must be open. (If closed, ANSI/ASTM Index Calculations are performed without 8dB Rule).

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characteristics of noise in addition to intensity. An example of earlier philosophy is reflected in Kryter's monograph on the "Effects of Noise of Man"[2]. This was a comprehensive review of all the literature on this subject up to that date, recognizing the need to consider the component frequencies and the bandwidth of frequencies that have common effects in evaluating the hazard of a given exposure to noise. For the next 15 or so years a number of damage-risk curves were produced by investigators, relating noise exposure level with duration of exposure and the frequency of the noise.

The use of A-weighted sound levels as a measure of hazard to hearing became common after 1967. The A-weighting network in a sound level meter electronically weights the amplitudes of sound in the various frequencies in the audible spectrum approximately in accordance with the average person's hearing sensitivity and sums the resulting weighted sound spectrum to obtain a single number (dBA).

Botsford[3], Passchier-Vermeer[4], Robinson[5], Cohen et al[6] found that A-weighted sound levels indicated hazard to hearing as well as octave-band sound pressure levels, noise rating numbers, etc. Because of its simplicity and accuracy in relating hazard to hearing, the A-weighted sound level was adopted as the measure for assessing noise exposure by the American Conference of Governmental Industrial Hygienists (ACGIH), in 1967.

The establishment of limits of noise exposure requires the consideration of many factors. These include: the results of surveys investigating noise-induced hearing loss and their applicability; methods of noise exposure control, their cost and feasibility; and of primary importance, the percentage of the group estimated to be protected by the established limits.

There has been a considerable controversy over the appropriate limits to be set, particularly in the United States. The development of regulations in the U.S. is of particular interest, as they most closely resemble the development of Canadian regulations.

The first Federal regulation in the U.S. limiting noise exposure, specifically to prevent hearing loss, was in the Health and Safety Regulations of the Public Contracts (Walsh-Healey) Act, May 1969[7]. This regulation incorporated the noise exposure limits adopted by the American Conference of Governmental Industrial Hygienists (ACGIH), shown in Table 1.1.

Scientific data at that time on noise-induced hearing loss indicated that a limit of 90 dBA for a 8-hour day, 40-h/week exposure over a working lifetime would protect about 90% of the people exposed to this level from a hearing loss substantial enough to interfere with speech communication. The ACGIH increased the limit 5 dB, for each halving of the exposure time, since there was evidence that the ear could tolerate higher levels for shorter periods of time. Further, if the noise is intermittent in nature (with rest periods between exposure), the ear could tolerate considerably more acoustical energy than for uninterrupted exposure to continuous noise. A limit of 140 dB peak sound pressure level was recommended at that time for impulsive noises.

In 1970 the Occupational Safety and Health Act (OSHA) was passed in the United Stated[9], and in 1971 the Walsh-Healey Safety Regulations were

adopted under this Act. In 1972 the National Institute for Occupational Health and Safety (NIOSH), reviewed the published data available on noise-induced hearing loss along with data from their research studies, and made recommendations to OSHA for a noise health standard[10]. One of the principle changes recommended by NIOSH was the lowering of the basic standard from 90 dBA to 85 dBA. To this date this recomendation (1982) has not been adopted in its entirety by OSHA.

On January 16, 1981, OSHA published 29 CFR Part 1910, "Occupational Noise Exposure; Hearing Conservation Amendment",[10A] in the U.S. Federal Register as a final rule to become effective April 15, 1981. This was amended on August 21, 1981[10B]. The exposure criteria of this regulation have been hotly disputed by employer and employee representatives, and still are not finally settled. The regulation as printed, allows a maximum time-weighted average sound level (TWA) of 90 dBA for 8 hours, with a 5 dB dose-trading relation. It does, however, require noise-exposure monitoring to identify employees exposed to a 8 hour TWA of 85 dBA or greater; in which case a hearing conservation program must be implemented, including baseline and annual audiometric testing.

In addition there has been a move in recent years, lead by the U.S. Environmental Protection Agency (EPA), to use a dose-trading relation of 3 dB as opposed to 5 dB. Simply expressed, this means that the limit is increased 3 dB for each halving of the exposure time. A 3 dB dose-trading relation is used almost exclusively in Europe on the grounds of it being the best relationship for hearing conservation[13]. The 3 dB dose-trading relation may be simply measured by the Equivalent Sound Level (L_{EQ}). The Equivalent Sound Level is a single value of sound level for any desirable duration, which includes all of the time-varying sound energy in the measurement period[11,12]. In his report "Effects of Noise on Man", Thiessen states "a good deal of legislation aimed at hearing conservation has been passed that allows 5 dBA higher levels for each reduction in exposure time by a factor of two; the supporting data for this originated primarily from temporary threshold shift (TTS) experiments. This trading relation is not accepted by all authorities and is probably, in many cases, a practical compromise. There is at least as much evidence that the increase should be just 3 dB instead of 5 dB, which also has the merit of simplicity of concept as well as dosage measurement."[14] It has the additional advantage of giving a simple method of handling impulse noise - which can be included in the L_{EQ} measurement. Impulse noise has long been felt to be responsible for a higher risk of hearing loss than that given by the total noise-dose criteria now used. This view was supported by the World Health Organization who recommended research in this area[15,16].

1.2 Occupational Hearing Loss in Canada

There have been very few published studies on occupational noise-induced hearing loss in Canada[14,53]. A recent study, "Progression of Noise-Induced Hearing Loss in Specific industries in Canada"[54], was submitted to the Non-Ionizing Radiation Section of the Department of Health and Welfare, March 1982. It is anticipated that this report will be published in the Environmental Health Directorate publication series.

A major deterent to the study, from the outset, was the reluctance of industries with ongoing hearing conversation programmes to make their records

available for the survey. To summarize the findings of the project as a whole: Serial audiograms from three industries taken over a 10 to 15 year period in relatively large samples of individuals, allowed the evaluation of the progression of hearing loss due to noise exposure within subject. This is in contrast to the traditional cross-sectional survey approach in which individuals each contribute one audiogram and the estimate of change in hearing is based on the average result for groups differing in age and/or years of exposure.

For each of the industries considered wide differences were noted across individuals in the rate of change with time. This might have been due to large variation in susceptibility. However, number of years of exposure at the start of the series of measurements could not be accurately estimated. Thus, a moderate change could mean either that the individual was resistant to noise and/or that he had already reached his asymptote for impairment. Significant differences due to job type were evident for the data of one company. These could not be related to noise levels, since precise measurements were not available. Even with these data, exact dosage would be unknown because of wide differences in complying with regulations for the wearing of hearing protectors. In general the greatest loss occurred at 4 kHz, and the number of frequencies at risk of exceeding the 25 dB HL fence increased with years of exposure. Across job types the rate of loss was roughly 1 to 2 dB per year, although younger subjects often showed rates in excess of 3 dB per year. By comparison control subjects were significantly less at risk and the slope in hearing loss with time was close to 0.0.

The major recommendations that might be made on the basis of this study are that there be closer monitoring and more complete record-keeping of both noise levels and noise dosage. These data might go with the individual as he transfers from job to job or across industries. Unless the usage of hearing protectors is strictly enforced, there appears to be little value in instituting a hearing conservation program. One encouraging bit of data garnered from one company was the greater compliance among younger employees, perhaps reflecting the success of relatively recent upgrading of teaching and advertising campaigns jointly by industry, union and Workman's Compensation Board.

2. Brief Description of Noise Dose Relations

One of the most critical decisions that legislators must make when formulating regulations to prevent occupational noise-induced hearing loss is to set limits of noise exposure. Since the amount of hearing loss incurred varies not only with noise level, but also with duration of exposure, noise-dose relations are equally important.

Early Canadian occupational noise regulations all used the 5 dB rule (a 5 dB increase in noise level allowed for a halving of exposure time). This rule was based on a limited number of studies, such as those by Kryter[17] and Sataloff[18], on temporary threshold shifts (TTS). These studies investigated the effect of intermittency and duration of noise exposure on the risk of hearing impairment. These works were used as a basis for the formulation of "Guidelines for Noise Exposure Control"[19] and the Walsh-Healey Act[7] in the United States (see Table 1.1). When the daily noise exposure is composed of two or more periods of noise exposure of different levels, the combined effect

is calculated as follows. If the sum of the following fractions:

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots \frac{Cn}{Tn} > 1$$

exceeds unity, then the mixed noise exposure should be considered to exceed the threshold limit value. C_1 indicates the total time of exposure at a specified noise level and T_1 indicates the total time of exposure permitted at that level.

For example, if a worker is exposed to 90 dBA for 6 hours and 95 dBA for 2 hours, according to Table 1.1, he is allowed 92 dBA for 6 hours and 100 dBA for 2 hours. The calculation is thus:

$$\frac{6}{8} + \frac{2}{6} = \frac{13}{12} = 1\frac{1}{12}$$

This sum is greater than 1 and therefore the worker has been overexposed.

Recently there has been a growing trend towards adopting the 3 dB rule. The 3 dB rule is based on the equal energy concept i.e. a noise level of 90 dB for 8 hours contains the same amount of energy as a noise level of 93 dB for 4 hours.

This concept may seem to be reasonable in terms of hearing conservation, but it does not take intermittency into account, i.e. that most exposure to hazardous noise levels is intermittent, thus reducing the hearing hazard. Unfortunatley there is increasing evidence that Temporary Threshold Shift (TTS), on which early intermittency studies were based, is not a good indicator of Permanent Threshold Shift (PTS), or permanent noise-induced hearing loss.

The variables in occupational noise-induced hearing-loss are numerous and include: differences in susceptibiity of the individual to noise, variation in noise exposure (duration and level), variations in audiometric testing, TTS, sociocusis (effect as hearing of noise from social as opposed to occupational activities), etc., making the analysis of these studies extremely complex.

In weighing the merits of the 3 dB and 5 dB trading relations, it would appear that the scientific arguments in favour of the 5 dB rule may not be as strong as appeared to be the case 10 years ago.

However, recent experiments have tended to confirm the protective benefits of intermittency[20,21]. On the other hand the 3 dB rule does enable impulse noise to be included in the measurement, possibly eliminating the need for a separate assessment of impulse noise to be made. Since many industrial operations contain high levels of impact (impulse) noise this could save a great deal of effort in the assessment of noise hazard. Further information on the effects of impulse noise on hearing is still required.

3. Summary of Canadian Legislation

Occupational noise legislation in Canada is for the most part covered by legislation having general health application and promulgated by the individual provinces and the Federal Government. In some provinces there is specific legislation for industries such as lumbering, mining, construction and

forestry. A detailed description of Canadian legislation aiming particularly at the protection of workers against the harmful effects of noise exposure in the work-place is given in Labour Canada's publication "1977 Occupational Noise Legislation"[22], and its latest amendment (October 1981). Since occupational noise legislation is in a continuing state of change in Canada, latest draft regulations are given, where publicly available, and tables of information are dated.

The Federal Government has two occupational noise regulations: The Canada Labour Code, Noise Control Regulations proclaimed in 1971, modified in 1973[23], which cover federal works' undertakings and businesses, and Treasury Board Standards issued in 1972 and modified in 1978[24], which have requirements similar to the Labour Code, but apply to Public Service departments and agencies. Some 750,000 people are covered by these two standards. New draft Treasury Board Standards, April 14, 1982, have been circulated[24A] and it is anticipated that these standards will be so modified shortly.

Other occupational noise legislation in Canada[25-45] falls within provincial jurisdiction, and thus applies to the majority of working Canadians.

Recently the Federal/Provincial Advisory Committee on Environmental and Occupational Health established a Working Group on Occupational and Environmental Noise Exposure and Hearing Conservation. The present terms of reference of this group is to prepare guidelines on occupational noise and hearing conservation regulations. It is hoped, in this way, to encourage national agreement in this area, with a firm scientific rationale. This work is supported by the Canadian Standards Association CSA Z107 Committee on Acoustics and Noise Control, whose Task Force on Occupational Noise recommended such action. The Task Force position is supported by the results of a comprehensive survey on the subject mailed across Canada to some 150 users of standards on occupational noise. There were over 60 replies and a need for national guidelines on occupational noise and hearing conversation regulations in Canada was clearly demonstrated.

3.1 Noise Exposure Limits

Limits of noise exposure prescribed in Canadian occupational noise legislation are shown in Table 3.1. It is generally assumed to be implicit in these regulations that noise levels are measured in a diffuse sound field with an omnidirectional microphone. It can be seen that there are some differences between the various regulations. The three main differences are (1) the variation between 85 and 90 dBA for an 8 hour per day exposure, (2) the variation between a 5 dB increase for a halving of exposure time prescribed in most provinces and a 3 dB increase for a halving of exposure time prescribed in British Columbia, and (3) combined or separate assessment of impulse noise. A recent trend toward 3 dB is reflected in draft Manitoba and Ontario legislation and in draft Federal Treasury Board Guidelines. This enables a combined assessment of impulse and steady-state noise. Eight provinces specify a separate assessment for impulse/impact noises that varies with the number of impulses, as shown in Table 3.2. The Federal Government presently prohibits exposure to impact/impulse sound "the peak sound pressure level of which, measured by a method acceptable to the regional safety officer, exceeds 140 dB unless that employee is wearing (prescribed) hearing protectors"[23]. Impulse

noise limits are not specified by 3 provinces. Impulse noise exposure level measurements are now incorporated with steady-state noise measurement in 1 regulation and 3 proposed regulations considerably simplifiying exposure calculations. Maximum impulse noise limits are also set for these 4 regulations.

At present Saskatchewan legislation specifies that noise levels in excess of 85 dBA be monitored and controlled, and aural protection of workers be required. Details of compliance, including an 85 dBA maximum daily 8 hour exposure level with a 3 dB increase for a halving of exposure time are given in a guide to compliance published by Saskatchewan Labour[44].

3.2 Alternative Noise Protection Measures

A summary of noise protection measures, other than noise exposure limits prescribed in Canadian Occupational Noise Regulations, is provided in Table 3.3.

Hearing Protectors

All provinces with occupational noise regulations prescribe hearing protectors under certain conditions. The majority (British Columbia, Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island and Quebec), state in general terms, that hearing protectors must be worn when employers are unable to reduce the noise below harmful levels (or the noise limit table indicated).

The Federal Government requires the use of hearing protection at noise levels over 90 dBA. Saskatchewan regulations, Manitoba and Ontario draft regulations, require hearing protection at noise levels over 85 dBA, as do Nova Scotia draft regulation guidelines[34A]. Proposed new Federal Treasury Board Standards require hearing protection at noise levels over 84 dBA.

Certain legislation (Federal Government and Quebec) specify that hearing protectors must comply with Canadian Standards Association (C.S.A.), Standard Z.94.2.1965, although only the Federal Government specifies "as amended". New Brunswick legislation specifies that hearing protectors must comply with C.S.A. Standard Z.94.2-1974, as does British Columbia. However legislation in British Columbia also has a table giving the C.S.A. Standard Class of hearing protector that may be worn in prescribed sound levels as in Table 3.4. Alberta legislation contains a similar table to that in Table 3.4, as does Ontario draft legislation. Ontario and Federal Treasury Board proposed legislation also include Noise Reduction Rating (NRR) hearing protector requirements.

Audiometric Testing

Three provinces, Alberta, British Columbia, and Saskatchewan specify requirements for audiometric testing (Saskatchewan in the compliance code) as do 3 draft provincial regulations. In Quebec, medical examinations may be required periodically, while the Federal Government specifies that audiometric tests may be required in certain situations >84 dBA in Treasury Board Proposed Standard. Nova Scotia have draft guidelines respecting noise exposure which include audiometric test requirements. Manitoba, New Brunswick, Newfoundland,

North West Territories, Ontario, Quebec, Prince Edward Island, and the Yukon, do not presently require audiometric tests.

Alberta legislation requires establishments with high noise levels to set up a hearing conservation programme which may include audiometric testing. When audiometric testing is required, it may only be conducted by qualified people. In this case the audiograms shall be made available to the Department of Health. Permissible background noise conditions for audiometric testing are specified in the regulations.

British Columbia legislation states that in any area where levels exceed the criteria, the employer is responsible for the establishment and maintenance of a hearing test program. The criteria are (1) 85 dBA steady noise and (2) an impact noise table as shown in Table 3.5. Details of when hearing testing should be conducted, by whom, and recording and keeping of the test results are also required.

Warning Signs

Although warning signs are prescribed in 6 of the present occupational noise laws in Canada, the requirements vary, particularly in the wording of the sign. The Federal Government, New Brunswick and Ontario, require warning signs where the level is greater than 90 dBA, Saskatchewan where the level is greater than 85 dBA. The Federal Government also requires signs where the impact noise is greater than 140 dB peak sound pressure level. British Columbia, requires signs where levels exceed the specified limits. Alberta, Manitoba, Newfoundland, Nova Scotia, Prince Edward Island, Quebec and Yukon, do not require warning signs.

The Federal Government and British Columbia require signs warning persons that a noise hazard exists and the type of hearing protection required. The Federal Government also requires the permissible exposure time to be stated. Saskatchewan requires the range of noise levels measured to be stated. New Brunswick requires signs which (1) warn individuals that hearing protectors are required, (2) are in contrasting letters at least 4" (102 mm) high and (3) are at least 18" x 24" (457 mm x 609 mm) in size.

Manitoba proposed legislation requires warning signs that not only clearly identify that a potential sound exposure hazard exists, but also specify the type of hearing protection required to be worn and used in that area. Draft Federal Treasury Board Standard requires clearly legible warning signs where employees may be exposed to an Leq of 90 dBA or above, indicating that the area is a high noise area and that hearing protectors are required.

Noise Surveys

Surveys of noisy places are only specifically required by the Federal Government, and Saskatchewan. In the proposed legislation they are also required in Ontario and Manitoba. The Federal Government states that noise surveys may be required where the safety officer believes levels are sufficient to impair employees hearing. Saskatchewan legislation states that all occupational establishments with noise levels > 85 dBA must be surveyed and documented within 3 months of the promulgation of the regulation and thereafter when there is reason to believe that substantial changes in noise levels have

occurred. Ontario proposed regulations contain a detailed code for noise measurement. In most provinces a noise survey comes under the powers of an inspector.

Noise and Vibration Control

Only Quebec mentions this subject. In their workplace regulations under the Quebec Environmental Quality Act[39] it is stated that noise and vibration capable of producing harmful effects on workers shall be reduced by one or all of the following means:

(a) isolation of noise sources;
(b) limitation of the intensity and duration of these noises; and
(c) installation of a soundproof device to isolate working areas from sources of noises or vibrations.

4. Hearing Conservation Programmes and Education

Whenever noise exposures are such that an unavoidable risk of permanent hearing loss exists, a hearing conservation programme should be provided[47]. Such programmes should contain 3 elements: education concerning the hazards of noise; education in the proper use and supervision of the wearing of hearing protection; and monitoring audiometry, including periodical medical examination, performed when necessary. Monitoring audiometry, if properly planned and executed, identifies workers at risk from incipient hearing impairment, so that they can be removed from the noisy workplace before excessive irreversible damage is caused. Since occupational noise regulations allow a certain risk of permanent hearing loss, a hearing conservation programme is highly desirable in addition to the specification of maximum exposure levels. Hearing conservation programmes are considered desirable when 8 hour daily exposures exceed 75 dBA[47]. Present concepts of acceptable risk and economic constraints limit the practical application of these programmes in most countries including Canada to levels around 85 dBA.

There is good evidence that well managed hearing conservation programs do protect the hearing of workmen[48]. Some aggressive hearing conservation programmes have been introduced into Canadian industry over the last 10 years and these should soon begin to bear fruit. More and more industries are becoming conscious of sound levels. Specifications for noise levels are being included when new machinery is ordered, and industries are becoming aware that very often the cost of engineering out noise is less than the cost of compensation paid for hearing loss. Awareness of the harmful effect of noise, both by labour and by management is probably the largest single incentive toward reducing occupational hearing loss.

Occupational noise regulations are beginning to recognize the importance of hearing conservation programs. Alberta regulations detail regular audiometric testing for noise exposed workers and a reporting system for those showing signs of hearing loss. British Columbia requires annual hearing tests for noise-exposed workers and records to be kept for the period of employment.

Draft Federal regulations specify audiometric tests for noise exposed workers and record keeping. The Ontario proposed regulation contains as Appendix Nb, January 19, 1982, a "Code for Medical Surveillance of Noise

Exposed Workers". The objective of the Ontario Medical Serveillance programme is to protect the health of workers by: (1) ensuring fitness for exposure to noise, (2) evaluating the effect of noise on workers, (3) enabling remedial action to be taken when necessary; and (4) providing health education. To achieve this the programme must consist of the following: (1) pre-employment and pre-placement examinations including audiometric tests, (2) periodical medical examinations, (3) health education, and (4) record keeping. The Manitoba proposed regulation is presented as a basic element of a hearing conservation programme. Other elements of the Manitoba programme will include development of educational materials for employers and workers, and a Code of Practice, which will contain detailed information to provide practical guidance with respect to provisions of the regulation. Exposure monitoring data, audiometric test results, health histories and associated reports must be maintained for the duration of a worker's exposure. The employer and workplace safety and health committee or worker representative are to be advised regarding the effectiveness of existing practices to control worker exposure to noise and the need for additional control measures.

5. Limitations of Present Regulations

Present Canadian occupational noise regulations are aimed primarily at protecting the hearing of the majority of workers in the speech frequencies. Protection of the hearing of acoustic frequencies outside this range, though even more noise sensitive, is only indirect and limited.

One of the major problems is lack of agreement on the appropriate methods of assessing both hearing loss and hearing disability and their relationship with each other. The question of what constitutes a hearing handicap and how it should be measured has not been resolved.

A successful method of assessing hearing handicap should take into account the economic and social handicap of the hard-of-hearing person and yet should be relatively quickly measured in a reproducible manner. At the present time evaluations of social and economic handicap are very time-consuming to undertake and are still in the experimental stage[49,50]. Current methods rely on the indirect relationship between hearing threshold as measured by pure tone threshold acuity and subjective complaints.

Another factor to be considered is that the effectiveness of any regulation relies heavily on its enforcement, voluntary or otherwise. Since most Canadian occupational noise regulations allow hearing protection to be used where the noise cannot be reduced to acceptable levels, the employer must not only provide hearing protection, but also ensure that it is worn properly to give adequate protection against hearing loss.

6. Worker's Compensation for Occupational Noise in Canada

In general industrial noise-induced hearing loss claims are accepted by the Workers' Compensation Boards if:

(a) there is an adequate history of exposure to hazardous noise in the workplace, and
(b) an otologist finds that the worker has a hearing loss that could have been caused by noise exposure.

It then has to be determined if the hearing loss is of sufficient magnitude to be considered pensionable.

Compensation for hearing loss due to occupational noise is dealt with very similarly in all provinces except British Columbia and Quebec, as shown in Figure 4.1. This figure shows that most provinces use a 35 dB low fence (the smallest amount of hearing loss that is compensated) and an 80 dB high fence (total deafness in one ear). The hearing loss calculation is an average of the 500, 1000, 2000 and 3000 Hz frequencies for each ear. The better ear is weighted by 5/1 which means that the disability rating for the better ear is five times as great as the rating for the poorer ear. The disability rating schedule used by these provinces is shown in Figure 4.2., Table A. Total deafness in one ear is thus rated at the equivalent of 5% total body impairment. Total deafness in both ears is rated at 30% total body impairment.

Slight differences in the way some of the provinces compensate hearing loss include (1) applying a presbycusis correction factor of 5 dB for each year over 60 (Newfoundland, Ontario and Alberta), (2) giving an additional 2% compensation for tinnitus (Ontario and Alberta), and (3) giving 60% disability for sudden complete bilateral deafness (New Brunswick and Alberta), who also have a schedule for unilateral deafness (see Figure 4.2, Table B).

Hearing loss compensation in the British Columbia regulation presently varies significantly from the above. However they apparently have proposed legislation to change the audiometric frequencies averaged to include 3000 Hz. Since this recommenation has been under consideration for several years now and immediate action is not anticipated[46], the low fence would also increase from 28 dB to 35 dB[46]. Their present disability rating schedule is shown in Figure 4.2, Table C. British Columbia awards a lower percentage compensation for total deafness, 3% for one ear and 15% for both ears, however their definition of total deafness in one ear is 68 dB rather than 80 dB, and thus the actual monetary compensation is claimed to be comparable with other provinces[51].

Only the province of Ontario includes guidelines to be taken for rehabilitation in its draft. These include authorization for hearing aids, lip-reading classes and vocational rehabilitation (the latter when employees are recommended for non-hazardous noise exposure employment).

Discrepancies exist in the relationship between percentage hearing loss and total pensional disability. In Canada total hearing loss is rated at between 15% and 50% of total pensionable disability. Blindness, on the other hand, is equated with 100% pensionable disability. It has been said that total hearing is one of the primary senses, and most jobs are impossible for the totally deaf and many are impossible for the hard of hearing[48].

Hearing loss produced by occupational exposure to noise has aroused increasing interest over the last decade[48]. One of the main reasons for this is the rise in the number of claims and the associated rise in the dollar cost of these. Figure 6.3, shows, as an example, the dramatic increases in Ontario over the last 30 years. It is likely, as the cost increases, and engineering technology improves, that high noise levels will be engineered out at source or masked. Until such time the cost of compensation is borne directly by industry

and thus passed back to the consumer.

7. Health and Welfare Programme in Occupational Noise

In protecting the health of Canadians from noise exposure, the Non-Ionizing Radiation Section (NIRS) of the Radiation Protection Bureau, Environmental Health Directorate, Department of Health and Welfare began by concentrating on the most significant health effect of noise - hearing loss - and the noise exposure that causes this effect and thus occupational noise exposure in Canada has been studied. There are also plans to investigate noise levels causing other health effects such as sleep loss, stress and annoyance, and the masking of important warning signals.

A background document entitled "Noise Hazard and Control", was published in 1979[53]. This doucment summarizes known health effects of noise (both auditory and non-auditory) indicates the major sources of noise, and describes Canadian noise legislation. It also indicates areas of incomplete knowledge, mainly related to noise-induced hearing loss, which are:

(a) the effects of impulse noise and continuous noise in the 4 - 6 kHz frequency range
(b) the accuracy and effectiveness of screening audiometric testing and screening audiometers
(c) the assessment of the total noise exposure of Canadians and its relation to hearing loss, and
(d) the investigation of the effects of hearing loss by various noise exposure limits.

Since then, noise levels and the progression of noise-induced hearng loss in specific industries in Canada have been evaluated.[54] The method of testing hearing (audiometric testing), and the acoustic accuracy of audiometers have also been investigated.[55] Current work is under way in conjunction with the provinces, to move towards consistent regulations for occupational noise exposure and hearing conservation. This is presently being conducted through the Federal-Provincial Advisory Committee on Occupational and Environmental Health.

Further surveys are planned on the measurement of noise from various sources, including sources emitting high frequency sound and ultrasound. Limited surveys of hearing acuity of people of various ages and noise exposures have been conducted. The contribution to hearing loss that can be related to age and exposure to various noise levels has also been investigated.

There are thus many present and future challenging problems to be investigated in the area of protection of health from acoustics radiation.

8. Conclusions

The main conclusions reached are as follows:

(1) Education of both employers and employees is an important element of most successful programmes for reducing occupational hearing loss.
(2) It is unlikely that levels below 75 dBA are harmful to workers.

(3) Considerable improvement of Canadian occupational noise regulations can be achieved by expanding them to include all the possible aspects of hearing conservation.

(4) The dramatic increase in number of claims for occupational hearing loss in the past decade and the cost of compensation provides a strong incentive for effective hearing conservation programmes.

(5) It would appear that the scientific arguments in favour of the 5 dB dose-trading relationship are less strong now than they were 10 years ago, although recent experiments have tended to confirm the protective benefits of intermittency.

(6) Further research is required into appropriate methods of assessing hearing loss and hearing disability and their relationship with one another.

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Table 1.1. Permissible A-weighted Noise Exposure Levels, (ACGIH 1967)[8].

Duration per Day Hours	Sound Level dBA*
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
3/4	107
1/2	110
1/4	115-C**

* Sound level in decibels as measured on a standard sound level meter operating on the A-weighted network with slow meter response.

** Ceiling Value.

Table 3.1. Current and Proposed Occupational Noise Regulations of Wide Application in Canadian Provinces (August, 1982).

Jurisdiction / Agency	Regulation or Guidelines or Proposal	Steady-State Noise			Impulse Noise			Year
		8 hour/day Limit[1]	Exchange Rate (dB)[2]	Maximum (dBA)[3]	Separate (S) or Combined (C)	Maximum (peak)[4]	Daily limit on number of impulses	
Federal Labour Canada	Regulation	92	5	115	S	140	No	Jan. 31 1973
Federal Health & Welfare (Existing)	Guideline	92	5	115	S	140	No	1972
Federal Health & Welfare (Proposed)	Proposal	90	3	-	C	-	No	April 14 1982
Alberta	Regulation 314/81	85	5	115	S	140	Yes	Sept. 15 1981
British Columbia	Regulation	90	3	105	S	140	Yes	Oct. 1 1979
Manitoba (Existing)	Guideline MR204/77 Sec 11 & 12	85	5	115	S	140	Yes	1977
Manitoba (Proposed)	Proposal	90	3	115	C	140	No	May 1982
New Brunswick	Regulation	90	5	115	S	140	Yes	1977
Newfoundland	Regulation O.C.799/79 Section 31(5)	85	5	115	S	140	Yes	1979
North West Territories	Regulation 271-77	90	5	-	-	140	No	June 1977
Nova Scotia	Regulation	85	5	115	S	140	Yes	1967
Ontario (Existing)	Regulation	90	5	115	S	140	Yes	1978
Ontario (Proposed)	Proposal	90	3	115	C	135	No	June 1981
Quebec	Regulation 44	90	5	115	S	140	Yes	Jan. 1981
Saskatchewan	Regulation[5] 567/81 Part IX	85	3	-	C	-	No	April 15 1981
Prince Edward Island	Regulation	Note 6			-	-		1975
Yukon								

Notes

1. Maximum permissible daily 8 hour time weighted average exposure level Leq (dBA).
2. Time/intensity doubling rate.
3. Maximum permissible hearing level without hearing protection (dBA).
4. Maximum permissible level (dB peak SPL).
5. Details taken from "Noise Regulations - A guide to compliance for occupational health committees, employers and workers", 6M/09/81, Saskatchewan Labour.
6. In Prince Edward Island levels are not specified in the legislation. Federal Labour Canada regulations are followed.

Table 3.2. Impulse Noise Exposure

Peak Sound Pressure Level dB	Maximum Number of Impulses Per Day
120	10,000
130	1,000
140	100
Greater than 140	0

Table 3.1 Noise Protection in Present and Proposed Occupational Noise Regulations. (August 1982)

Jurisdiction / Agency	Noise Protection Measures							Hearing Conservation Program
	Hearing Protectors			Audiometric Testing Required	Warning Signs Required	Noise Survey Required	Noise & Vibration Control Specifications Required	
	Required when occupational exposure limits are exceeded	Meet CSA Std.	BBR Std.					
Federal Labour Canada	>90 dBA or >140 dB peak SPL	✓	-	Conditional	✓	✓	-	-
Federal Health & Welfare (Existing)	>90 dBA or >140 dB peak SPL	✓	-	Conditional	✓	✓	-	-
Federal Health & Welfare (Proposed)	>84 dBA	-	✓	✓ 84 dBA	✓	✓	-	✓
Alberta	✓	✓	-	✓	-	-	-	✓
British Columbia	Detailed level requirements	✓	-	✓	✓	-	-	✓
Manitoba (Existing)	✓	-	-	No	-	-	-	-
Manitoba (Proposed)	>85 dBA	-	-	✓	✓	✓	-	✓
New Brunswick	✓	✓		No	✓	-	-	-
Newfoundland	✓	-	-	No	-	-	-	-
North West Territories	✓	-	-	No	-	-	-	-
Nova Scotia	✓ At discretion of inspector	-	-	Specifications (included in guidelines).	-	-	-	-
Ontario (Existing)	✓	-	-	No	✓	-	-	-
Ontario (Proposed)	>85 dBA	✓	✓	✓ 85 dBA	-	✓	-	✓
Quebec	✓	✓		No	-	-	✓	-
Saskatchewan	>85 dBA	-	-	Recommended	✓	✓	-	-
Prince Edward Island	✓	-	-	No	-	-	-	-
Yukon	-	-	-	No	-	-	-	-

Table 3.4. Hearing Protector Requirements in B.C. Legislation[28].

C.S.A. Standard Z94.2.-1974 Class	Sound Level dBA (Note 1)
C	85-93
B	94-99
A	Over 100
A	Impulse (Note 2)

Note 1: This is understood to mean steady level[46].

Note 2: This is understood to mean where Impulse Noise exceeds the B.C. Schedule for impact noise where the maximum number of impacts per 24 hour period are given for specified peak sound pressure levels[22,46].

Table 3.5.

British Columbia Schedule for Impact Noise Levels Above Which Audiometric Testing Routinely Required[28].

Peak Sound Pressure Level (dB)	Maximum Number of Impacts Per 24 Hour Period
Over 135	0
134	112
131	225
128	450
125	900
122	1800
119	3600
116	7200
113	14400

Table 6.1.

Workers Compensation for Occupational Hearing Loss in Canada

Audiometric Frequencies Used (Hz)	Method of Calculation	Low Fence (ANSI/ISO)	High Fence (ANSI/ISO)	Better Ear Correction	Presbycusis Correction	% Per Decibel loss		Maximum % for Total Deafness			% for Tinnitus	Provinces
						Partial (both ears)	Unilateral or Acute Traumatic Hearing Loss	One Ear	both Ears	System Complete Bilateral Deafness		
500, 1000, 2000	average	25 dB	65 dB	5/1	.5 dB each year over 60	not known	-	5	30	30-60	-	Quebec
500, 1000, 2000, 3000	average	35 dB	80 dB	5/1	.5 dB each year over 60	A*	-	5	30	-	-	Newfoundland
500, 1000, 2000, 3000	average (rounded up to next 5 dB increment)	35 dB	80 dB	5/1	-	A*	B*	5	30	60	-	New Brunswick
500, 1000 2000, 3000	average	30 dB	80 dB	5/1	.5 dB each year over 60	A* extended down to .1s at 30 dB	-	5	30	60	-	Northwest Territories
C O N F I D E N T I A L - N O T D I S C L O S E D												Nova Scotia
500, 1000, 2000, 3000	average	35 dB	80 dB	5/1	.5 dB each year over 60	A*	-	5	30	-	2	Ontario Manitoba P.E.I.
500, 1000, 2000, 3000	average	35 dB	80 dB	5/1		A*	-	5	30	-	-	Saskatchewan
500, 1000, 2000, 3000	average	35 dB	80 dB	5/1	.5 dB each year over 60	A*	B*	5	30	60	2	Alberta
500, 1000, 2000	average	28 dB	68 dB	4/1	-	C*	-	3	15	30	-	British Columbia

* A, B, C, see Figure 4.2 Tables A, B, and C.

Table 6.2. Percent Disability For Varying Degrees of Hearing Loss.

Table A. Partial Hearing Loss Where Both Ears are Affected

dB Hearing Loss	% Disability
35 dB (ANSI/ISO)	.4
40	.7
45	1.0
50	1.4
55	1.8
60	2.3
65	2.8
70	3.4
75	4.0
80	5.0

Table B. Unilateral Deafness (Alberta) or Acute Traumatic Hearing Loss (New Brunswick)

dB Hearing Loss	% Disability
30 dB (ANSI/ISO)	1
40	2
50	3
60	4
70	5

Table C. Non-Traumatic Hearing Loss (British Columbia)

Loss of Hearing in dB	% of Total Disability	
	Ear Most Affected PLUS	Ear Least Affected
0 - 27 (ANSI/ISO)	0	0
28 - 32	0.3	1.2
33 - 37	0.5	2.0
38 - 42	0.7	2.8
43 - 47	1.0	4.0
48 - 52	1.3	5.2
53 - 57	1.7	6.8
58 - 62	2.1	8.4
63 - 67	2.6	10.4
68 or more	3.0	12.0

Table 6.3.

Province of Ontario: WCBO Industrial Hearing Loss Claims (58)

Years	No. Claims (c) +	No. Pensioned (p) +	% c/p	Aver. PD	New Annual Payments $ (estimated)*
1950-1960	130	39	30	3.96°	1,404
1961-1965	312	62	19.9	3.96	4,910
1966-1970	862	238	27.6	3.96	18,849
1971	370	130	35.1	3.96	51,480
1972	382	148	38.7	3.96	58,608
1973	582	208	35.7	7.02*	146,016
1974	986	483	50.0	7.02	339,066
1975	1519	639	42	7.02	448,578
1976	2463	1066	43	7.02	702,000
1977	2405	1364	57	7.02 est	957,528
1978	2091	1338	64	7.02 est	939,276

° from Alberti et al (53) .
* computed from patients studied.
PD = pensionable disability.
Mean age of claimants between 1971 and 1975, 55.7 years.
Aver. PD includes presbycusis correction; as applied at time.
Assumption made that presbycusis correction and frequencies averaged changed January 1, 1973.
Until 1974 claimants pensioned only when out of noise.
From 1974 onwards claimants may receive pension and continue working in noise.
+ Courtesy Dr. Margaret Hayley, Hearing Consultant, Workmen's Compensation Board of Ontario.
* expressed in 1976 dollars.