National Health, Safety & Environment

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NOISE

From Awareness to Action

INTRODUCTION

Every day workers face many hazards in their jobs — some easier to spot than others. One of these hazards —noise — probably affects more workers than any other. Almost 70 per cent of workers experience noise in their workplace. To protect themselves, workers must learn about noise, how the ear functions, and the effects of noise on the body.

Steel mills invariably are noisy places. There are a variety of power tools, heavy equipment and other machines contributing to the din of the workplace. According to Ontario Workers Compensation statistics from 1985 to 1988 an average of 100 basic steel mill workers per year suffered permanent hearing loss or impairment. Most people working in steel mills are very aware of the nuisance posed by noise, but not everyone realizes the health problems it can cause.

Our union has been surveying the Canadian membership for a couple of years now. The results of the Occupational Disease and Cancer Survey are very alarming. On the average we are discovering 27 cases of hearing loss per local. There is no greater occupational hazard reported in our survey. This number is far above the Canadian national average and is a very strong indicator that our work is having a big impact on our health and our lives.

Though the Workers Compensation Boards for the Canadian provinces have been paying our members for noise induced hearing loss, no amount of money can restore the quality of life that is gone when you lose your hearing. Though these statistics have no real faces attached to them, most Steelworker members and their families are affected by noise induced hearing loss. We did not go to work to die or to be maimed. We went to work to earn money in order to support our families and make the world a better place for our children.

WHAT IS NOISE?

Noise has defined as unpleasant or unwanted sound. It is everywhere in modern society, be it traffic noise, unpleasant music, or the clamour of daily life. Some of this is noise we choose. But we can turn off radios and televisions, and close our windows. There is one major area of daily life, however, where there is no escape — the workplace.

Sounds from a variety of processes reach workers' ears by various means: by reflection off other surfaces, directly from the surrounding air, by vibration of the building floor or supporting beams in the workplace. As well as traveling through solids, sound can also travel through liquids. Although noise strikes us in many ways, levels and directions, there are certain basic characteristics to all sound. Sound is a form of energy, acting like the waves a stone creates when thrown into a calm pond. Vibrations or ripples of energy spread out from the source of sound and become weaker as they move farther away from the centre. There are two ways to measure the energy of sound — **frequency and intensity.**

Frequency (Hertz)

Frequency, or pitch, is measured in a unit called a Hertz (Hz). One Hertz is equal to one cycle per second. The greater the number of Hertz, the higher is the pitch or frequency of the sound. A high pitched sound such as a referee's whistle is very different from a low frequency sound such as a knock on the door. We call sounds with frequencies below 20 Hz **infrasound**. Sounds with frequencies greater than 16,000-20,000 Hz are called **ultrasound.** Sounds below 20 Hz and above 20,000 Hz are inaudible to humans.

Intensity (Decibels)

Intensity is an objective measure of the energy of sound. It is objective because we can read it directly from an instrument. Subjective measurement of sound (how the ear measures sound) is called loudness. It depends entirely on what the human listener hears.

The distance sound travels depends on its intensity. In open air, sound waves will spread outwards from the source in all directions until they meet some form of interference. The energy scatters at a rate of one over the square of the distance from the source. In other words, two feet from the source the noise intensity will only be one quarter of the intensity found at one foot from the source. At five feet, a sound will only be one twenty-fifth of the intensity found at one foot from the source.

What happens with noise in open air seldom applies in the workplace. Here, reflection, refraction (breaking up), absorption, and other forms of interference break up the pattern of sound. Still, frequency and intensity are important to keep in mind when trying to reduce noise exposure.

The range of human hearing is large. It is so large that it is difficult to include the whole range on one scale. So, instead of measuring sound intensity by a straight scale (based on addition) we use a logarithmic scale (based on multiplication). The unit of measure of this scale is the **decibel (dB).**

Decibels are measures of the intensity of sound above a given reference level which is usually the threshold of human hearing (0 dB). **Every increase of ten decibels represents an increase of sound intensity by ten times.** A reading of ten on the decibel scale represents a sound ten times more intense than a sound of zero dB. A reading of 20 on the dB scale represents an increase of sound intensity by another factor of 10, or sound 100 times more intense than 0 dB. We express 10 x 10 as 10^2. A 90 dB reading measures a sound 10^9 (1 with 9 zeros behind it) times more intense than 0 dB. Read 10^9 as "10 to the ninth power". We know 10^9 as the number one billion.

An easy way to use the dB scale is by using the "doubling" factor. **For every 3 dB change there is either a doubling or a halving of noise intensity**. So an increase of noise level from 90 to 93 dB actually represents a doubling of sound, not just "a bit over" the 90 dB standard. A further increase to 96 dB represents another doubling so 96 dB is four times (2 x 2) the allowed level of 90 dB. Similarly a decrease of 3 dB from 90 dB cuts the intensity of sound in half.

If two noises each of 90 dB are added, their combined noise level is 93 dB. This is significant in the workplace, because it means that a noise level of 93 dB is actually twice as intense as a noise of 90 dB and therefore twice as damaging to health.

For increases in dB:

- a 1 dB increase is a 25% increase in noise,
- a 2 dB increase is a 60% increase in noise,
- a 3 dB increase doubles the noise level.

For decreases in dB:

- a 1 dB decrease reduces the noise by 20%,
- a 2 dB decrease reduces the noise by 35%,
- a 3 dB decrease reduces the noise by half.

There are different types of dB scales. The scale most resembling the response of the human ear is the "A" scale. All instruments measuring noise in the workplace must use the "A" scale, and all noise exposure of workers must be measured in dB(A). (Measured on the "A" scale.)

Intensity of Sound From Some Common Sources of Noise

Noise Source	*Decibel Level*
Threshold of hearing	0
Leaves rustling, very soft whisper	10
Inside the average house	50
Normal conversation at one metre	60
Office tabulation machine or Shouting to be heard a metre away	80
Lathes	90
Pneumatic drill	100
Woodworking shop	110
Riveting on a steel tank	130
Jet engine	140

Exposure at 90 dB causes approximately 29 workers out of 100 to suffer substantial noise induced hearing loss. At levels of 85 dB, 15 workers out of 100 lose hearing. Even at 80+ dB, 3 workers out of 100 will still suffer a loss. These figures exclude age-induced hearing loss, which some suspect is also primarily the result of our industrial society.

Infrasound and Ultrasound

Infrasound (less than 20 Hz) is not uncommon where heavy machinery is running and may affect several organs in the body. Exposure to infrasound may lead to dizziness, change in pulse rate, nausea, impaired eyesight or hearing, increased blood pressure, or fatigue. In most cases protective equipment does not stop the penetration of infrasound, which is usually accompanied by vibration. Heavy types of industrial equipment emit ultrasound (16,000 - 20,000 Hz and higher). The tool or machine, which makes noise at these frequencies, may cause tissue damage in the fingers, commonly called Raynaud's phenomenon. Ultrasound also causes irritation or annoyance, stress and fatigue. It is, however, easier to screen off than infrasound.

More work has been done on the effects of infrasound than on ultrasound. A wide range of effects is connected to exposure to low frequency sound. Unfortunately, the government does not believe there is any need for special regulations to reduce infrasound and ultrasound to safe levels in the workplace.

THE EAR

We hear because our ears are able to receive sound waves, change them into nerve impulses and pass these impulses to the brain for decoding. The ear is a complex organ divided into three sections. The **outer ear** includes the auditory canal. The **middle ear** is a cavity containing the three auditory ossicles (or small bones). The **inner ear**, a complex set of tubes and channels that includes the cochlea, is enclosed in solid bone.

Hearing is a complex series of chain reactions. Sound enters by the outer ear, moving into the auditory canal where it strikes the eardrum. The eardrum vibrates and these vibrations are transmitted through three small bones in the middle ear into the oval window of the inner ear. They then pass into the snail-shaped cochlea, where they move a system of fluids. This triggers thousands of small, hair-like sensory cells, which transform the sound waves into nerve impulses and in turn transmit to the brain. It is these cells that are affected by noise, and once damaged, they can never be replaced.

As long as hearing is normal, the ear can detect very faint sounds and briefly tolerate very loud noises. A person with normal hearing can detect sound waves from a very low frequency (20 Hz) to a very high frequency (20,000 Hz). The range of greatest sensitivity is between 2,000 and 3,000 Hz. Speech ranges between 250 and 8,000 Hz. Anyone who has a hearing impairment in this range suffers serious social and personal handicaps.

HEARING LOSS

Partial or complete hearing loss can be the result of many different factors. Interference with the transmission of sound wave vibrations to the inner ear results in **conductive** deafness. Causes include plugging of the outer ear canal (wax, foreign objects, etc.), or hardening or puncturing of the eardrum. This type of deafness may also occur because of damage to the bones in the middle ear. Unlike noise-induced hearing loss, conductive deafness can often be cured.

Sensori-neural deafness is caused by damage to the cochlea, the auditory nerves or their pathways. The major cause of sensori-neural deafness is exposure to loud noise. While doctors can diagnose it, there is, unfortunately, no cure. Most cases of occupational hearing loss are sensori-neural deafness.

Noise can damage the ear instantaneously (acoustic trauma). It can also numb the ears for a limited time (temporary threshold shift). As well, it can permanently alter the ear's sensitivity to certain frequencies (permanent threshold shift).

Acoustic Trauma

Acoustic trauma can be caused by impact noises generated by explosions or sledge blows against metal. It may rupture the eardrum beyond repair, or break or move the bones of the middle ear. However, most hearing damage appears after a person has been exposed to noise for a long period of time, rather than this instantaneous trauma.

Temporary Threshold Shift

Another type of hearing damage is temporary threshold shift, or a numbing of the ear sensitivity for a limited time. If noise frequency levels are too high, the hair cells of the cochlea will be temporarily damaged. This is essentially an acute but reversible adaptation of the hair cells to an excess of sound energy. If for example, you were exposed to 100 dB for 10 minutes, a hearing test would probably show that your sensitivity to sounds at 4,000 Hz was reduced by 15 dB, resulting in a temporary threshold shift of 15 dB at that frequency. If, after work, you have to turn up your car radio louder than usual, this is definitely a clue that you were exposed to too much noise. If the length of exposure is short, and exposure occurs infrequently, the cochlea will bounce back over time. More chronic damage occurs, however, when exposure to noise becomes prolonged and constant.

Whatever the noise frequency range, the threshold shift always occurs at 4,000 Hz. The reasons for this phenomenon are not known, but it is a basic characteristic of hearing loss caused by noise. It is assumed that the part of the cochlea that responds to 4,000 Hz is set in motion irrespective of the frequency of the noise and is, therefore, the part of the hearing mechanism that is first and most severely damaged. This is right in the middle of the ear's range of greatest sensitivity — sounds such as the human voice fall into this range. Therefore, workers whose hearing is damaged in this manner carry this impairment into their social and personal lives. It may also create additional hazards at work — workers may not be able to hear warning signals or voices in the event of an emergency.

Permanent Threshold Shift

As the length of exposure and noise intensity increase, both the temporary threshold shift and the recovery time needed become greater. The problem of course, is that most workers do not have enough time to fully recover from the effects of noise exposure between shifts. Consequently, the damage to the hair cells becomes cumulative and permanent. This kind of damage is called permanent threshold shift.

Once hair-like sensory cells in the cochlea are damaged — they can never be replaced.

Signs of Hearing Loss

Most workers will not notice the gradual loss of their ability to hear until their hearing has become permanently impaired**.** People who say they are used to noise at work, or that it doesn't bother them, are not immune to the real damage noise does to their bodies; they have likely already suffered hearing loss to some extent. For instance, a new worker coming into a noisy work area for the first time will go home after the first day with a significant temporary threshold shift; he or she will be extremely tired, will likely have a headache, and may experience a ringing in the ears. Sounds will be muffled, as if people are speaking to him or her through a blanket. Over the next few days, the noticeable effects will not be so severe. Eventually the worker is "accustomed" to his or her hearing loss. For a certain length of time, these effects are reversible; this period varies with the type and intensity of the noise and with the individual's response to it, but it usually lasts about one year. After this, the approach of deafness may be halted, but there can be no return to normal hearing.

There are two symptoms of hearing loss that workers can look for in themselves and their co-workers. First is the loss of the ability to communicate in group situations, especially when there is background noise. This may not be easily recognizable, because face-to-face encounters will not be a problem. (People who gradually lose their hearing will learn to lip-read.) The second symptom, appears later, and is the blaming of other people. Workers who make comments like "people don't speak clearly any more" may be projecting the source of the difficulty onto others rather than recognize that the problem is their reduced ability to hear.

Occupational hearing loss occurs in the hair cells of the cochlea. Too much noise wears out the hair cells, causing nerve deafness. Photographs of the cochlea taken through an electron microscope show hair cells broken, bent out of shape, or completely missing as a result of noise. This damage is permanent and cannot be remedied by a hearing aid. In some situations a hearing aid may be helpful, but it will never replace your own hearing.

There are three major symptoms associated with advanced noise-induced hearing loss. First, you do not hear everything: certain high frequency sounds are lost forever and the sounds become inaudible, and the sounds you *can* hear must be louder in order for you to hear them. Second, sounds are likely to be distorted. This occurs because higher frequencies are more seriously affected than lower frequencies. Within the speech frequencies, for example, consonants are higher than vowels and are therefore lost first. This makes even simple statements difficult to understand. Third, you may have difficulty hearing when there is a great deal of background noise; you may also have difficulty locating the source of sounds. This kind of disability can change a social gathering from an enjoyable experience into a nightmare.

Other Hazards Which Affect Hearing

Noise is the main cause of hearing loss, but other workplace hazards can induce it as well. A **hard blow** to the temporal bone could cause a concussion of the internal ear, resulting in hearing loss. **Welding sparks** are another hazard to hearing. A small spark that enters the ear could burn right through the eardrum, causing a chronic inflammation of the ear.

In combination with noise, certain other hazards such as **vibration** and **solvents** increase the risk of hearing damage. For instance, it has been demonstrated that the vibrations of a chain saw increase the harmful effects of its noise more than would be expected. Some studies seem to indicate that people who work with solvents in noisy environments run a higher risk of hearing loss than those who work in the same noise without the solvents.

VIBRATION

Noise and vibration frequently come from the same source. Like noise, vibration can bring about serious health problems for workers. For instance, exposure to hand-arm vibration results in diseases such as white finger and gangrene of the fingertips. Whole body vibration occurs where heavy, noisy or fast moving machinery operates. Whole body vibration also affects drivers and those exposed to hand-arm vibration.

The definition of vibration is a rapid motion (or oscillation) back and forth of an object. (e.g., tool handle, truck seat or shop floor.) This motion may be in any of three directions, (up/down, side to side, to/fro) or in all three directions. The risk level depends on:

Acceleration of the Surface: the measure of force on your body, measured in meters per second squared (m/s^2).

Duration of Vibration: the longer the time of exposure, the greater the damage.

Frequency of Vibration: the number of times the vibrating surface moves in one second. The frequency is measured in Hertz.

Vibration from pneumatic tools is of relatively low frequency (16 to 1000 Hz).

From a worker's health viewpoint, frequency is divided into two areas:

1) the whole body is affected at 1 to 80 Hz;

2) the hand-arm is affected at 4 to 2000 Hz.

Whole-Body Vibration — the complete body is vibrated up and down, side to side or back to front (driving, shop floor).

Hand-Arm Vibration — the hands and arms are affected (pneumatic tools, grinding).

Note: There may be some overlap of the types of vibration, such as driving a truck and controlling a vibrating steering wheel.

Health Effects of Vibration

Health hazards associated with whole body vibration exposure are: sickness, imbalance, blurring of eye sight, slowed reaction time, hernia, varicose veins, slipped disc, disorders of the digestive system, and damage to the bladder, breathing, genitals, muscles and bones. Effects of hand-arm vibration include those of whole body vibration and cramp-like pains in hands and feet, headache, fatigue, sleeplessness, irritability, "white finger", and gangrene.

Many of the effects are not caused by vibration alone. Other factors are important. Shift work, job stress, stationary positions, and heavy work are contributing factors. Workers subject to both vibration and loud noise (a common occurrence) experience a greater narrowing of the blood vessels (vasoconstriction) than they would from either hazard alone.

OTHER HEALTH EFFECTS OF NOISE

As much as hearing loss hurts us, it is not the only harmful effect of noise. We must take into consideration the other health effects on the body caused by noise.

Immediate effects include:

- ✓ increase in heart rate;
- ✓ rise in blood pressure;
- ✓ slow down of digestive processes;
- ✓ increase in muscular tension;
- ✓ psychological disorders.

Long-term problems include:

- ✓ cardiovascular disease;
- ✓ gastrointestinal disease;
- ✓ fatigue;
- ✓ psychological disorders;
- ✓ tinnitis;
- ✓ voice problems.

Obviously, the whole body suffers from the effects of noise. As sound reaches the ear and changes into nerve impulses sent to the brain, other impulses reach the central nervous system and hormonal system. **Tinnitis,** a tormenting ringing in the ears, can be more disturbing than hearing loss itself. Some researchers believe noise can also impair vision and affect balance. Constant high levels of noise create a general stress response in the body. The **stress response** can act as a warning signal to alert a worker to danger. However, it too cannot be maintained for prolonged periods without harmful effects. Hormone production and blood pressure increase, and blood vessels in most areas of the body contract. Fats are released into the bloodstream and the rate of breathing increases. This continued stress response has a deteriorating effect on the body.

Another serious hazard associated with noise is its **interference with communication on the job**. This is especially dangerous in areas where numerous activities are taking place at the same time. In many work situations, the ability to hear approaching machinery or warning shouts or signs can mean the difference between life and death for a worker.

AUDIOMETRIC TESTING

Audiometric testing does not control noise, but only measures the effects of noise on a worker's hearing. The only person who should conduct these tests is a qualified physician of the worker's choice. Then only the worker can decide whether to continue working in the problem environment. An audiometric test should:

- set baseline hearing levels;
- identify hearing loss;
- identify workers who require further investigation;
- alert workers to the effects of noise and importance of hearing protection; and
- trigger an evaluation of workplace noise control programs.

These tests have very little preventive value. Even under the best of conditions, the margin of error for audio-metric testing is 10 decibels. Unless workers work in extremely noisy conditions, it may take years before damage can be measured. By that time, damage to the worker is permanent, and it is likely that his or her co-workers have been equally affected.

Testing for hearing damage while workers are still exposed does nothing to address the problem. In Western Australia, where mandatory audiometric testing was part of the noise regulation, tests have done nothing to promote engineering controls. They have only promoted discrimination against workers. Fortunately, a relentless campaign by Australian Labour has convinced their Minister of Labour to drop mandatory audiometric testing from the state's noise regulation. Labour has come to know all too well that medical tests do not enhance workers' health, because they do not address noise problems at their source.

In spite of all the evidence that noise is devastating to exposed workers, present legislation continues to allow an "acceptable risk". Inexpensive technology to reduce noise at the source exists, yet many argue the economic burden to implement such technology is too heavy and would force whole companies to close their doors. Investing only in audiometric testing and personal protective equipment gives workers the impression that the problem is being addressed. In reality, however, these stopgap measures do little to reduce workplace noise. The sad irony is that money invested in audiometric testing could be used to reduce levels of noise by altering the noisy equipment.

Further, as in Australia, audiometric test files "could" be used against workers. These tests "could" be used to deny workers compensation for their occupational hearing impairment. They "could" also be used to argue that a workers hearing impairment existed before he or she began to work.

NOISE-LEVEL METERS

Audiometry measures the effects of noise on hearing. From a prevention point of view, it is more important to monitor levels of noise at the work location so that appropriate controls can be put in place. Workers know from experience, where the noise problems are, and there is a relatively simple procedure for converting this knowledge into hard data.

An instrument known as a sound-level or noise-level meter can be used to measure noise levels at any particular point in the mills. There are different types of noise measuring instruments, which should be selected according to the type of noise and the type of exposure being measured. While continuous noise (such as the sound of a motor) remains relatively constant, some noise sources generate sounds, which fluctuate widely over a given period of time. Intermittent sounds (e.g., from drilling or sawing) play an important role in determining the overall noise level a worker is exposed to over a particular period of time. An integrating sound level meter is equipped with features that enable it to average noise levels over such a time period. The readings obtained are called equivalent sound levels.

Noise-level meters usually have a choice of scales, which measure all the intensities of the various frequencies in a sound. The "A" scale must be used because it most closely approximates human hearing, by giving stronger weighting to higher frequencies than to lower frequencies.

WORKPLACE NOISE ASSESSMENT

To reduce noise, we first need to analyze the workplace. A noise measurement survey will determine the frequencies of the highest noise levels. This will help you determine which areas require which controls. For example, hearing protection and insulation materials filter noise at particular frequencies. Once you identify the noise frequencies in your workplace, insulating materials and hearing protection can be chosen to be of most benefit. Above 110 dB hearing protection becomes ineffective. The best hearing protection available can only reduce noise by about 18 dB, and noise travels through the skull in any case. We know the technology exists to eliminate noise at the source. Unfortunately, the main emphasis on noise control to date has been at the worker.

The really shocking part is that, of all the workplace hazards, noise is among the easiest to control. The stumbling blocks have been a lack of political will and an overabundance of economic pressure. Knowing the effects of noise on the workers is only the first step. A thorough and accurate assessment is essential to identify problems of noise in the workplace.

The Walkthrough

The purpose of a walkthrough or survey is to determine the levels of noise in each area and chart these levels on a block diagram. Complete lists are important for identifying the number of workers exposed, and the amount of exposure. Use block diagrams to identify problem areas. These are areas you need to monitor constantly to be sure the noise levels don't increase (due to lack of maintenance procedures, for example). Add noise information to basic workshop plans, or draw the block diagram as you proceed through your inspection. Knowing the types of controls already in place is important. A survey also serves as an opportunity to identify areas where engineering controls would be valuable in reducing noise levels. Keep in mind that if we effectively reduce the noise level by 3 dB, we have cut the intensity of the noise in half.

There are certain basic procedural techniques to follow in a normal noise survey. Use a sound level meter with a dB(A) scale. One which will measure peak as well as standard noise levels is the best choice. Take noise measurements as close as possible to where a worker would normally work. Readings at the worker's eye level or the position of his head are standard. If the worker must move during his work process, or to operate his equipment, take readings over the range of head positions. Noise levels from machines should be taken from a distance of one to three metres.

The goal is to build a noise profile to transform into a kind of topographical map for noise in that work area. The report summary should give times, locations, dates, those present, machinery or work processes used, hearing protection available, and any concerns coming out of the survey. This report will be very useful to the Joint Health and Safety Committee, or any joint noise abatement program.

PRINCIPLES OF NOISE CONTROL

There are many methods of putting controls in the workplace. Worker must have input at the design stage of any control program to ensure that problems are being dealt with at their source.

The only permanent solution is to reduce noise to the lowest possible level through engineering controls. Although often considered too costly, some of the most effective controls at the source are very inexpensive. For example, proper silencing of pneumatic air exhausts, and repairs of steam lines or air lines can actually pay for themselves in improved energy efficiency. An organized control program can progress from the easiest and least costly solutions to the more complex and costly programs. A complete noise measurement program may involve taking octave band measurements to determine the frequency range of particular noise sources. Operating some noise sources while turning others off is another part of this program. A program like this is costly and should be handled by people trained for it, but it does present a complete picture.

We already know that low-pitched noise has a low frequency and high-pitched noise high frequency. This relationship follows the reverse order as well. A high frequency action produces a high frequency sound. You can hear this when you rev your car engine. When the car engine is idling, the noise is low pitched. As the engine accelerates, the pitch goes up. This knowledge can be applied in the workplace, too. High-speed equipment produces high frequency noise. This noise is more irritating than lower-pitched noise but more easily absorbed, more quickly dissipated and more easily controlled.

High frequency noise has different physical characteristics than low frequency noise. Low frequency noise bends through holes and around barriers. High frequency noise tends to travel more in a straight line, so it will bounce back from a barrier, and travel straight through a hole. High frequency noise attenuates (gets less noisy) over distance more quickly than low frequency noise, but is more annoying at the same intensity. It is also more easily absorbed than low frequency noise.

CONTROL AT THE SOURCE

The most effective way to reduce noise is at the source. The technology to eliminate noise exists and is used quite extensively in domestic and other non-occupational settings. In many cases, however, employers have chosen the supposedly less expensive but also less effective route of personal protective equipment. In fact, again, many effective controls are inexpensive and proper maintenance of equipment can actually help to keep costs down. There are two basic ways of eliminating noise at the source — through the design or modification of machinery itself and through isolation or enclosure of the noise source.

Examples include:

- the use of effective mufflers and silencers on equipment;
- modifying existing equipment with quieter parts (e.g., replacing small-diameter, high-speed fans with large-diameter, low-speed fans — they are quieter);
- enclosing noise-producing parts or the whole machine, (e.g., enclosing air compressors with acoustical (sound-absorbing) material and supplying them with effective mufflers at the intake and exhaust);
- isolation of noisy machinery (e.g. keeping cement mixing equipment and air compressors outside immediate work areas);
- substituting a noisy machine or operation with a quiet one; and
- proper maintenance and operation of equipment (e.g., replace worn parts such as bearings which create noise).

Obviously, it is far better to start off using quiet equipment than to try to modify noisy equipment. Whenever new equipment is needed, the joint committee should be involved in comparing noise and vibration specifications so that the equipment with noise and vibration-reducing features can be purchased.

Recently, the growing awareness of noise-induced health problems has prompted the production of quieter equipment. Anti-noise legislation in the United Kingdom and a number of other countries has forced equipment manufacturers to produce quieter machines. U.S. legislation authorizes the development and enforcement of noise emission standards for products identified as major noise sources. In Sweden, manufacturers determine what noise levels are acceptable to the users of the equipment and build the machines accordingly. Listed below are two actual examples of noise reduction from the British Trades Union Congress handbook on noise at work:

- generator test rigs, when enclosed, dropped from 102 dB to 83 dB;

- woodworking machines, when enclosed, had a reduction from 110 dB to 85 dB.

Other factors, which will reduce noise and vibration, include reducing the speed of moving parts, balancing rotating parts (to eliminate noise through structural vibration) and using sound-absorbing and vibration-damping materials and parts. Using equipment mounts and situating vibrating parts inside machines on shock absorbing mounts will also help to reduce noise. The noise from a vibrating surface can be reduced by making it smaller, or by cutting openings in it. For instance, a vibrating guard of wire mesh will be less noisy than a large, sheet metal guard.

As noted above, equipment that is regularly maintained will also produce less noise and vibration than equipment which is poorly maintained. In some cases, noise hazards can be created or worsened by a lack of maintenance. Loose parts can rattle and grinding noises can occur as the result of inadequate lubrication. It is especially important to maintain noise control devices which are added or built into machinery. A muffler will not be effective if it becomes loose or worn out.

Control Along the Path

Noise can be controlled along the path through *separation* of the worker from the noise source and through the use of sound-absorbing materials and barriers or reflectors.

Examples include:

- barriers, screens or shields;
- sound-proof cabs on operating equipment.

Sound booth in a hot strip-finishing mill exemplifies controls along the path.

Another, less desirable way of separating the worker from the noise source is to enclose the worker in a soundproof control console or acoustic booth.

Sound-absorbing materials can be used in a workplace, in machinery, or in duct systems. They are most effective if installed close to the noise source, and are better at reducing high-pitched rather than low-pitched noise. They provide no protection, however, to the machine operator who is working directly in the middle of a noisy area.

Doubling of the distance between a worker and a noise source has the effect of reducing noise between 3 dB and 5 dB. However, as the worker moves further than this there is less noise reduction because sound is reflected off the hard surfaces of the work environment. Large sound barriers or reflectors may also reduce noise transmission to some degree. But these are also more effective in reducing high-pitched noise than low-pitched noise.

Control at the Worker

Controlling the worker is the least effective method of controlling noise, yet it is too often the only method used. By using methods like rotating workers or shutting off certain machines, employers can expose workers to high levels of noise for short periods and still meet the requirements of the Health and Safety legislation. Programs like this already exist in uranium mines for example. The net effect is more workers are exposed.

Unfortunately, it is likely that noisy equipment will only be replaced over time, therefore ear plugs or muffs may be the only protection available to workers in the meantime. **Protective equipment such**

as ear plugs or ear muffs should be considered an interim measure, to be used while ongoing attempts are made to develop more effective controls, or in situations where these controls are impossible

Hearing protection must be adequate for the noise hazard and is only effective if it is used properly. For example, safety glasses and earmuffs must often be worn together, but the gap caused by the arm of the glasses at the earmuff seal significantly reduces the effectiveness of the muff. The maintenance of earmuffs must include regular checks of their seals, tension and acoustical properties. Repairing and sanitizing should only be carried out by properly trained personnel.

The amount of noise energy, which gets through hearing protection, depends on the frequency of the noise. Different protectors are more effective at different noise frequencies. An octave band analysis is part of the information you need to select the correct hearing protection.

The heavier the earmuff, the less comfortable it is likely to be. This becomes even more important if the muff has to be worn constantly. Further, earmuffs that fit correctly (that is, have good tension and a good seal) are likely to be very hot.

In some cases, earplugs may be a suitable form of protection. Workers must remember, however, that disposable plugs must not be recycled and reusable plugs must be cleaned regularly. A serious ear infection can result if plugs are not cleaned and the infection can be as harmful to hearing as noise.

Again, repairing and sanitizing protective equipment must be done by properly trained personnel for proper hygiene and an adequate level of protection.

Removing the protection for very short periods can destroy the effect for the rest of the day. According to one source, muffs which give overall 20 dBA protection provide only 6 dBA protection if worn for three out of four hours.

Administrative controls such as rest breaks away from the source of noise are important. Rest breaks are an acknowledgement of the discomfort involved in wearing hearing protectors and lessen the possibility of workers removing the protectors.

It is also crucial that workers are given a choice of a variety of devices — no single device can reasonably be expected to suit all workers.

But workers need not accept the compulsory use of hearing protection. They can work through their Joint Health and Safety Committee to push for controls at the source and along the path. Employers must respond to such committee. Committees can also request independent test results of hearing protection's effectiveness.

LEGISLATION

Some Regulations state that noise in the workplace should be reduced to less than 90 dB. If this is not possible, then the hours of exposure should be limited (not more than eight hours at 90 dB, four hours at 95 dB, two hours at 100 dB, etc.) or appropriate ear protection should be worn. When a worker is exposed to 115 dB or more, hearing protection must be worn. Many people believe that all of these limits should be lowered. While far from ideal at the Federal level, for instance, regulations stipulate that no worker other than persons driving trucks weighing 4,500 kg or more, shall be exposed to noise levels exceeding 87 dBA over a maximum period of eight hours. One source states that exposure (over a working lifetime) to noise at an average intensity of 90 dB will result in approximately 42 in every 100 workers being deafened. A report prepared for the Ontario Workers' Compensation Board also stated "90 dB is not a safe level below which deafness could not result. It is well-accepted that cases of hearing loss have occurred and will continue to occur at noise exposure below this level."

CONCLUSION

Workers and their representatives should continue to press for the most effective controls to reduce noise and vibration in the work place. The results of noise and vibration surveys can be used to identify problems and create a prioritized list of recommendations. Unresolved demands can become bargaining issues. Health and safety representatives should insist that personal protective equipment is professionally maintained and that equipment and tools used on the job are regularly serviced. It is also important that workers receive training on noise and vibration hazards so they become aware of the hazards to which they may be exposed. Finally, political action will also be necessary to gain improved standards and tougher regulations for noise control.