INTRODUCTION

Studies over the past few years have clearly shown that noise levels are relatively high on tractors, and other farm machinery, and that farmers as a group suffer from noise induced hearing loss (3, 5, 6). Evidence is increasing that noise may also affect man's non-auditory systems and his psychological state (4), but much less research work has been done on this subject, especially at the farm level (18). Industry has already recognized the noise hazard for its workers, and standards have been developed to guide the protection of hearing by either reducing noise level, reducing exposure time, or supplying ear protection (2, 9).

Noise standards need to be established for farm workers as well, to guide manufacturers in designing their product, and supply a basis for hearing protection. Unfortunately, industrial noise standards are not necessarily directly applicable to the farm situation because exposure times and exposure intervals during the work day and during the entire year are not strictly comparable. This factor, along with some discrepancies in the industrial noise standards, explains the slight variations in safe levels now being assumed in studies that attempt to reduce the noise hazard for farmers. Both industry and users have made some effort to combat the problem with good progress in many cases.

The purpose of this paper, then, is to provide background on the noise problem, and develop some suggestions as to action that might be taken.

TABLE I FAMILIAR SOUNDS RELATED TO SOUND PRESSURE LEVELS

<table>
<thead>
<tr>
<th>Sound Pressure Level (dB)</th>
<th>Sounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Whisper at 5 ft.</td>
</tr>
<tr>
<td>30 to 40</td>
<td>Country residence</td>
</tr>
<tr>
<td>40 to 60</td>
<td>Noisy home; average office</td>
</tr>
<tr>
<td>50 to 60</td>
<td>Average conversation</td>
</tr>
<tr>
<td>60 to 70</td>
<td>Average traffic at 100 ft.; dishwashers</td>
</tr>
<tr>
<td>70 to 80</td>
<td>Automobiles at 20 ft.</td>
</tr>
<tr>
<td>80 to 90</td>
<td>Heavy traffic at 25-50 ft.</td>
</tr>
<tr>
<td>90 to 100</td>
<td>Inside subway car; food blender</td>
</tr>
<tr>
<td>100 to 110</td>
<td>Woodworking shop; power lawn mower</td>
</tr>
<tr>
<td>110 to 120</td>
<td>Unmuffled motorcycle; thunder</td>
</tr>
<tr>
<td>120 to 130</td>
<td>Hydraulic press at 3 ft.; pneumatic riveter at 4 ft.</td>
</tr>
<tr>
<td>130 to 140</td>
<td>Threshold of pain</td>
</tr>
<tr>
<td>140 to 160</td>
<td>Jet engine</td>
</tr>
</tbody>
</table>

Sones, a linear measurement of sound, may also be used where the apparent loudness of a complex sound may be altered by the effect of a large single frequency component. A more complete discussion of sound pressure level is beyond the scope of this paper, but many of the references offer a thorough definition (1, 13).

Noise can be measured by instruments based on a sound detection device (microphone) that is sensitive to fluctuations in barometric pressure. After appropriate amplification, frequency weighting and filtering (when used) the microphone output is registered on a meter. Noise measurement requires careful consideration of the instrument’s mechanical and electrical characteristics, to be sure that frequency response time, and other factors are compatible with the noise being measured.

The basic sound level meter contains different networks that give greater weighting or importance to sounds in certain frequency ranges than in others. These networks are usually referred to as the A, B, and C scales (16). The ear also does not respond in the same way to similar sound pressure levels at different frequencies, and the “A” network of the sound level meter is intended to approximate this type of response. Thus noise measurements of human concern are measured by the “A” network and the results signified as dB(A).

Sound level meters can also be equipped with filters to allow measurement of noise intensity at different frequencies. The filters will pass a specified frequency band, depending on the type of instrument. For example, analyzers that could be used might include octave band analyzers, one-third octave band analyzers, ten cycle constant band-width analyzers, etc. Each analyzer will obtain different data from the same noise. An “octave” is an arbitrary sound frequency...
range having the upper frequency twice the magnitude of the lower frequency.

HEARING

The ear, along with the ear drum and bones of the middle ear, transforms the pulsating waves of air pressure to vibrations in the inner ear. Here, these vibrations are picked up by 400,000 hair-like protrusions that, in turn, signal the auditory nerves (7). Over-exposure due to length of time or sound intensity weakens these hairs so that they no longer respond to the sound. Sufficient rest (elimination of exposure to these high noise levels) can restore the system to normal, but as over-exposure continues more and more of the hairs refuse to recover and permanent hearing loss results. Furthermore, the ability of the inner ear to recover from fatigue varies between individuals. Also, hearing ability at the higher frequencies is lost first, affecting music appreciation before impairing the ability to understand speech.

The “threshold of good hearing” curve (Figure 1) shows that the young ear can detect frequencies between 20 and 20,000 Hz; but outside the speech range (approximately 60 dB, at 300 to 3,000 Hz), the sound pressure levels must be greater before the sounds can be heard. With age, and more seriously with ear damage, the threshold will shift to higher sound pressure levels and the ability to hear higher frequencies will be lost. The intent of most hearing protection criteria is to safeguard the ability to hear normal speech.

SAFE LEVEL CRITERIA

In order to establish safe sound levels for humans, certain conditions are required:

1. The harmful effects that occur at various noise levels must be known, as well as the intensity and duration of the noise to be controlled. Also, the effect of fluctuations in exposure levels and the daily and yearly exposure patterns, with intervening rest periods, must be known.

2. A decision must be made as to the type and extent of hearing protection that will be provided. Present noise control standards generally assume, first of all, that hearing, but not non-auditory or psychological aspects will be considered. Also, the concern is essentially with the protection of the ability to hear normal speech.

3. Since the susceptibility of individuals varies, some portion of the population, say 90 or 95% will be chosen as a reasonable level to receive protection.

Figure 2 depicts some of the safe noise levels that have been established, for the frequency range and daily exposure times shown, to protect industrial workers from hearing damage. The curve notations indicate the different information sources. ISO is International Organization for Standardization per Hansen et al (10), Alta. is Alberta Department of Health (9), and the others are Blatherwick (3) and McKeon*. The assumptions used to establish each safe level curve were not made obvious, except that it is generally the speech range of hearing that is intended to be protected. Differing assumptions may account for the discrepancy of the ISO curves from the rest.

Industrial standards are difficult to apply to the farm environment. This is due to the large variation of a farmer’s exposure time to that of an industrial worker on a daily and yearly basis. Insufficient data are available to describe the farmer’s exposure pattern, as well as the expected damage to hearing from such exposure patterns. In a comprehensive review of noise induced hearing damage conducted for the SAE (Society of Automotive Engineers), the Southwest Research Institute (18) states that...

...criteria established for Industrial noise environments will not accurately predict hearing loss for agricultural and construction environments, and in all cases, these criteria prove to be too conservative”. They further point out that to properly define the operator’s noise dosage “...the total definition of the noise exposure (time, sound pressure level, age, etc) must be considered and at this time, this data is not available”.

Despite this lack of information, some safe risk levels need to be used in order to combat noise problems until further data have been gathered. This leads to some discrepancy in the safe noise levels presented in various publications. In general, there is a tendency to use the eight hour risk curve established for industry (Figure 2). In terms of overall noise levels, conservative estimates use 85 decibels as an upper noise limit, while others consider 90 decibels as a reasonable minimum noise risk level. The National Institute of Agricultural Engineering (20), has shown a range of noise limits depending on the percent of population to be protected (Table II). The Organization for Economic Co-operation and Development (15) specifies a maximum tractor noise level of 89 dB(A) measured at a distance of 7-1/2 metres.

TABLE II. NIAE SAFE NOISE LEVELS DEPENDING ON THE PORTION OF THE POPULATION TO BE PROTECTED

<table>
<thead>
<tr>
<th>Percentage of Population to be Protected</th>
<th>Equivalent Sound Level (dB-A)</th>
</tr>
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<tbody>
<tr>
<td>98</td>
<td>81</td>
</tr>
<tr>
<td>95</td>
<td>85</td>
</tr>
<tr>
<td>90</td>
<td>88</td>
</tr>
<tr>
<td>80</td>
<td>92</td>
</tr>
</tbody>
</table>

*Personal communication with C.E. McKeon, Vehicle Systems Department, Ford Tractor Operations, Birmingham, Mich., 48012.
While noise levels need to be controlled to protect hearing ability, specifying a noise level that is too conservative is uneconomical. The cost of any sound reduction provided by the manufacturer will be more or less proportional to the amount of reduction achieved.

THE CURRENT SITUATION

A number of tractor noise surveys have been made, and have provided ample evidence of high noise levels (Figure 3). The industrial eight hour exposure curve is shown for reference. Sources of these curves are B (Blatherwick, 3), Donaldson (6) and Walker (21). It seems obvious, for most tractors, that a risk of hearing damage exists in the speech range. However, it is interesting to note that the noise levels at the higher frequencies, required for music appreciation, are considerably lower than the proposed safe level.

Surveys of the hearing ability of farmers have verified that farm noise dosages likely exceed safe levels. An extensive survey in Saskatchewan (5) concluded that farmers in the 30 and over age group suffered noise induced hearing loss likely to cause impairment of the ability to discriminate between sounds and to impair communication in the presence of background noise, compared to the normal hearing loss due to aging. The amount of hearing loss increased with the age of the farmer and with the size of his farm. It was found that by the age of 65, the majority of farmers had hearing losses that impaired the normal hearing of speech.

Other surveys have also found that tractor drivers have greater hearing loss than the general population, for example in Alberta (3) and the U.K. (20).

REDUCTION OF NOISE EXPOSURE

Ear protectors are a low cost, immediate form of adequate protection that is available for all farmers regardless of the noise level of their particular tractor. Of these ear protectors, the fluid seal muffs provide the greatest attenuation and are the most practical and reliable device for the farm operator to handle. The amount of noise reduction to be expected of various ear protectors (Figure 4) has been given by the American Speech and Hearing Association (16).

The major disadvantage of the fluid seal muffs is that they may be uncomfortable to wear, particularly in hot weather. A South Dakota study (b) showed that most farm tractor operators would wear ear muffs at least a portion of the time during tractor operation. Some found the muffs more objectionable than others but their acceptance increased after becoming accustomed to wearing them. It is interesting to note that Farm Machine Design Engineering (12) reported that Massey Ferguson is providing free ear defenders with every new tractor (in Britain).

In the past, manufacturers have spent some effort in trying to define the noise sources and modify the tractor design to reduce the noise levels. However, this approach seems to have been proven costly and impractical. The most significant noise control that can be obtained is the installation of adequate mufflers with the exhaust outlet well above the level of the operator’s ear. An example of the noise reduction that can be obtained with a muffler on a diesel tractor was shown by Walker (21). Compare Walker’s unmodified noise level in Figure 3 with the level achieved in Figure 5 using a super muffler.

With the growing popularity of tractor cabs a more reasonable solution presents itself. At least two manufacturers have recently shown that acoustically designed cabs can produce a safe level for the tractor operator. The cabs are anti-vibration mounted and are acoustically treated with noise barriers and sound absorbing materials. Vibration dampening is also utilized on the tractor sheet metal and fenders. Examples of the noise levels achieved by these methods were given (Figure 5) by McKeon, Egging, and the NIAE (19). These levels generally fall below the 8 hr risk curve, contrary to existing noise levels (Figure 3). The same 8 hr risk curve is shown in both figures to aid making comparisons.

Tractor purchasers may gain the information necessary to choose tractors that offer lower sound levels through the recent addition of noise measurement to the items reported by Nebraska tests (8). Included in this reference are the first published noise level measurements, on their 1970 test tractors, that were made by Nebraska.

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**Figure 3.** Tractor noise levels.

**Figure 4.** Pure-tone attenuation characteristics of some ear protectors.

**Figure 5.** Tractor noise levels achieved by modification.

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RECOMMENDATIONS

The following recommendations suggest action that can be taken regarding the farm noise problem.

1. An intense campaign is currently required to encourage all farmers to buy and use proper ear muffs to obtain immediate protection from high levels of tractor noise.

2. Recognizing that there are insufficient data to establish confident safe noise level criteria at present, efforts should be made to study the situation and possibly work with other groups to establish noise criteria for the intermittent exposure patterns found in the farm situation. An important group to include here is the NRC Associate Committee for Environmental Quality (14), which is intended to supply the information necessary to formulate various standards. Also, guidelines are provided by the American Industrial Hygiene Association (2).

3. Research should be undertaken to obtain the data that are missing on exposure times and exposure levels in the total farm environment for various farm operations throughout Canada.

4. Industry should be encouraged to bring into production acoustically designed tractors.

5. A standard report form should be encouraged for noise surveys and noise studies to insure that the terms of reference, instrumentation limitations, and other factors affecting the results are fully reported.

6. Research should be undertaken on the effects of noise other than hearing loss.

7. Present noise reduction methods should be evaluated and compared for their effect on the operator's comfort, and his ability to monitor and control his equipment.

SUMMARY

The existence of excessive noise levels and the resultant phenomenon of farmer hearing loss has been well documented. Although exposure pattern data are insufficient for agricultural workers, some estimate of safe limits can be borrowed from industrial standards. Adequate ear protection is available at low cost for farmers operating noisy equipment. The growing popularity of tractor cabs, and the recent inclusion of noise level measurement in the Nebraska thesis, along with the recently reported success of manufacturers in acoustically treating cabs suggest that in the future farmers will be able to purchase tractors that provide safe noise levels. Much less is known about noise level exposure in the farm environment in other situations, and from other equipment besides tractors. More information is also required on noise effects other than hearing damage. Another unanswered question is what amount of machine noise that the operator uses to monitor machine functioning will pass various noise attenuation devices.

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REFERENCES