

REVIEW OF LITERATURE ON ACOUSTIC WARNING SIGNALS AND FORKLIFT TRUCKS

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1. INTRODUCTION

A recent literary review (Laroche & Denis, 2000) of the norms, regulations and scientific articles related to acoustic signals on forklift trucks discerned this problem. This project brought forth 10 major conclusions :

1. A significant number of fatal accidents occur each year and many involve pedestrians travelling near forklift trucks. In the past 24 years, Quebec has had a serious or fatal accident involving contact between a pedestrian and a forklift truck every two years. Between 1994 and 1997, the CSST compensated 583 victims of forklift trucks, 54% of which were pedestrians hit by these vehicles. In the United States, OSHA counts, on average, 11 deaths and over 9500 injuries related to forklift trucks yearly.
2. Forklift trucks are used in all industrial settings to ensure material transportation or storage.
3. Most norms and regulations do not insist on the installation of reverse alarms on forklift trucks since the rear view is not considered obstructed on this type of vehicle. However, certain regulations (e.g. OSHA) forbid the disconnection of reverse alarms already installed on forklift trucks.
4. The reverse alarms currently available do not fulfill the auditory warning devices' conception criteria proposed by Tran Quoc and Héту (1996).
5. Forklift operators' work is very complex and involves repetitive movements in order to ensure some safety behind the vehicle.
6. No security device (e.g. mirror, video camera, horn), taken in isolation, seems sufficient in ensuring the safety of pedestrians travelling near forklift trucks.
7. The devices available for obstacle detection (e.g. infrared system) are not yet sufficiently reliable to ensure safety behind forklift trucks.
8. In view of all the limits of the many security devices, many researchers recommend the use of reverse alarms while taking into account the environmental constraints and work execution constraints (e.g. ambient noise, number of vehicles simultaneously travelling in reverse).
9. Not one Quebec or Canadian manufacturer produces forklift trucks. Consequently, easily implemented short-term solutions must be found seeing that foreign manufacturers will unlikely apply solutions involving the design of forklift trucks, in the near future.
10. Prior to proposing the use of reverse alarms, it seems justifiable to proceed with the development of a questionnaire geared towards the forklift truck operators, the pedestrians and the interveners as well as an observation chart of the forklift truck's movements in different industrial settings, in order to determine the reverse alarm's relevance in these settings.

There seems to be situations in which the reverse alarm could be harmful and others where it could represent an indispensable security device. However, the characteristics of the current reverse alarms and horns do not ensure their audibility. The recent works of Laroche & al. (1995), Laroche & Lefebvre (1998), Guindon (1996) and Wilcox (1994) are sufficiently eloquent to support proceedings aiming at the improvement of this type of auditory warning signal.

2. ACOUSTIC SIGNALS AND FORKLIFT TRUCKS

Wilcox (1994) addressed the question of acoustic signals on forklift trucks by first presenting the most common causes of accidents involving a forklift truck striking a pedestrian. According to Wilcox, four major causes can explain the majority of accidents : 1) forklift trucks are relatively quiet, 2) forklift trucks are used in noisy environments, 3) pedestrians and forklift trucks cannot be completely isolated, and 4) there is restricted visibility on the forklifts. In Wilcox's opinion, many accidents would be prevented if the pedestrians were better informed of the forklift's presence. Visual and auditory modalities should therefore be solicited. Thus, the use of auditory and visual warning signals should be seriously considered.

This author finds it difficult to explain why reverse alarms are not mandatory on forklift trucks. He seems to attribute this fact to the manufacturers who claim, particularly in the context of legal pursuits, that their vehicles are safe and that security systems, such as reverse alarms, do not need to be added to them. Thereafter, Wilcox attempts to demonstrate that the manufacturers have every intention to improve the safety of their vehicles and discusses the 11 myths associated to this problem. Every one of these myths will be presented and briefly discussed for it allows the importance of the problem to be properly discerned.

1. Pedestrians get used to the alarms and these thereby lose their efficiency over time :

According to Wilcox, people get used to false alarms but do not get used to the useful information that inform them on the presence of forklift trucks.

2. The use of warning signals leads to more negligent operators :

Wilcox finds no evidence in the literature that having access to a security device, such as an auditory signal, influences the operators' degree of vigilance.

3. The presence of many forklift trucks, each equipped with a warning signal, would create confusion :

The main question is whether it is safer to be surrounded by forklifts that are seen and heard or that aren't. Wilcox presents the following analogy : is it safer to cross an intersection filled with noisy vehicles or silent vehicles?

4. Warning signals cause difficulties and are annoying :

Warning signals cause difficulties because reverse alarm manufacturers have not included a sound quality criterion in their design. According to Wilcox, modifying the alarms' acoustic characteristics could solve this problem. Moreover, Wilcox adds that even if it were difficult to completely eliminate all difficulties created by alarms, it would nonetheless be preferable to use them than to allow for more accidents to occur.

5. As opposed to work on the forklift's design, forklift truck operator training and a safe work environment represent better solutions for risk control :

Wilcox recalls the hierarchy that ergonomic professionals generally apply : 1) eliminate the risk, 2) protect only when the risk cannot be eliminated, 3) inform only when the risk cannot be eliminat-

ed nor controlled through protection, and 4) consider training only when the risk cannot be treated with any of the three alternatives. The reasoning behind this hierarchy is that nobody is perfect.

6. The accidents are caused by a task that demands too much of the victim's attention and not by faulty forklifts :

What surprises Wilcox in this myth is that the situation where an individual is too concentrated on his/her task and has not heard the forklift, is precisely the condition under which reverse alarms should be considered in order to draw the individual's attention.

7. Accidents can be avoided, for example, by driving in reverse or by looking around the load :

Wilcox notes that it is unreasonable to think that all forklift truck operators will continually "strain their necks" to optimize their visual field. Ergonomically, the forklift truck operator's position represents a risk for all sorts of chronic problems if the driving is done in reverse. Consequently, the manufacturers cannot blame the forklift truck operators for the accident when, in fact, the vehicle's design does not respect the ergonomic criteria.

8. The clients should decide what to install :

Wilcox specifies that the clients who purchase the forklift trucks are not experts in this field. They are thereby not qualified to evaluate the risks associated to these vehicles, or to know what should be done to improve the level of safety.

9. The use of warning signals for the forward and backward courses would create confusion and danger for the workers who are unaware of the direction in which the forklift truck is moving :

Wilcox easily objects to this myth by reporting that the idea is to inform the individuals of an approaching forklift, regardless of its direction.

10. Workers could disconnect the warning devices :

According to Wilcox, the risk of employees disconnecting the device is associated to the quality of the device's design and is not a valid argument against the installation of such a device.

11. The warning devices should be adjusted to the workplace's particularities :

There are many ways to adjust a warning signal to the reality of the environment. For example, the warning signal could be adjusted according to the ambient noise. Many adjustments are technically feasible.

All arguments enumerated by Wilcox argue in favor of the use of reverse alarms on forklift trucks. Another author also supports this view. Miller (1988) reports some examples of serious accidents that involved forklift trucks and insists on the importance of auditory warning signals, either a horn or a reverse alarm, due to the forklift truck operator's complex task.

Amongst other topics, Guindon's (1996) report addresses the analysis of certain situations involving the perception of the forklift truck's horn. No reverse alarms were studied in this project because, according to Hétu, who was responsible for the project, these alarms are often judged harmful and do not transmit useful information due to the cacophony often induced and the habituation phenomenon.

On this basis, we can contend that an unquestionable doubt seems to subsist as for the pertinence of reverse alarms. As for the results related to the horns, they are rather eloquent. Out of 235 situations where horns are used in 8 different establishments, only 30 condi-

tions were judged adequate when using the Detectsound software (Laroche & al., 1991) as an analysis tool. These results lead Hétu and Denis (1995) to conclude that we should have access to horns with multiple frequency components for which the intensity would be automatically adjustable as a function of ambient noise.

3. CONCLUSION

In summary, the relevance of reverse alarms on forklift trucks is not clearly established yet, especially in those situations where the forklifts often circulate in reverse and where the noise level is already relatively elevated. Moreover, the spectral and temporal characteristics should be defined with greater specificity in order to ensure the audibility of reverse alarms in the conditions where it would be pertinent. There does not seem to be any perfect short term, or medium term, solutions, whether it be in visual ergonomics (use of luminous signals, of video systems or of mirrors) or in the arrangement of the forklift truck operators' work position. On the basis of the above stated studies, the use of reverse alarms would consequently be recommended while taking into account the apprehensions also stated. Further studies should be realized in order to establish the conditions for which the reverse alarms would be recommended.

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