SINGLE PARAMETER ELEVATOR COMFORT EVALUATION

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1. ABSTRACT

Designing, manufacturing and installing comfortable elevators is not straightforward. Recently, major lift companies' efforts to improve comfort on their installations have increased considerably, following a parallel path to travel speed and tougher user demands.

One of the problems when trying to improve elevator comfort is its assessment. There are two main obstacles in considering comfort as a single parameter. Firstly, comfort is obviously a subjective feeling, and therefore can hardly be measured by technical means. Secondly, discomfort is brought along by different sources, making the task of reducing it to a single parameter especially difficult. Due to these difficulties, defining elevator comfort as a single parameter remains an unsolvable problem.

This report describes how ORONA approached the problem, taking into account the effect of multiple vibration sources on the lift according to international standards. Correlating the measures to a broad range of existing installations accounts for the subjective nature of the problem.

2. EFFECTS OF VIBRATION ON THE HUMAN BODY

Vibration affects the human body in various ways. It can be disturbing or even harmful. Vibration inside a lift is assumed to be of relatively small intensity, never reaching harmful levels, but the duration of exposure is taken to be high. Disturbance in that case usually causes the user to feel sick, or leads to similar unpleasant feelings. Discomfort is defined as such.

The main parameters affecting vibration are frequency and amplitude. Different frequencies are sensed in different ways by the human body, and thus affect the way in which discomfort is felt. Vibrations at frequencies below 0.5 Hz are most likely to produce motion sickness, frequencies around 5 Hz are said to be very amplified inside the body as a whole, and interfere considerably with some activities such as writing. Vibration frequencies of up to about 10 to 20 Hertz can be especially annoying for head movement or talking, and higher frequencies up to 60 Hertz can induce vibrations in smaller parts of the body, such as the eyes.

3. KINDS OF VIBRATIONS EXISTING ON LIFTS

Every moving machine vibrates, including lifts. The main source of vibration in lift installations, and generally in mechanical systems, is also the main energy source, namely the engine. In a lift installation two kinds of vibrating movements can be clearly distinguished:

- Vibrations **directly produced by the engine**, such as those induced by unbalance or misalignment. These vibrations then travel through different components of the installation (e. g. the cable or car frame) until they reach the cabin. They usually happen under determined conditions (for example, when the installation operates at half load). Lift manufacturing companies try to neutralise them in two ways: by producing the minimum vibration (i.e. balancing the machine) or by introducing damping components at the car panels to stop the vibrations from reaching the cabin. Since lift machines typically run at over 1300 rpm, these vibrating phenomena usually have frequencies ranging from 20 Hz to over 100 Hz, although half the rotating frequency of the machine is sometimes encountered. This frequency range is beyond that affecting comfort. However, if the machine produces a high amount of these vibrations, their contribution to user discomfort might not be negligible.

- Vibrations **induced by the movement of the cabin**: When the cabin begins to move, the lift is somewhat similar to a car moving on a road. Unevenness of the road or irregularities on the wheels can cause the car to vibrate, and a bad suspension system can enhance those vibrations inside it. In a lift system, guides play the role of the road, sliders or rollers are similar to wheels, and springs or rubber elements (between the rollers or sliders and the car frame or between the car frame and the cabin) are the lift's suspension system. Irregularities on the guide rails or defects on the rollers or sliders induce movement, which can be enhanced if the springs or rubber systems are not properly selected. This kind of vibration happens randomly, with no fixed pattern, although subsequent travels will have the same vibrating pattern, since guide irregularities remain basically constant. This kind of vibration is usually at a frequency of between 1 and 10 Hertz, which, as will be shown in the next chapter, is most prone to cause discomfort.

In summary, two kinds of vibrations might affect lifts; the ones produced by the machine and those produced by the movement of the cabin. Both have very different characteristics and frequencies (and are easily distinguishable in measurements), and both affect the user's comfort in different ways. Nevertheless, both have to be considered when assessing discomfort.

4. OBTAINING A SINGLE COMFORT PARAMETER

4.1 THE ISO 2631 STANDARD. DISCOMFORT ASSESSMENT

As seen in the previous chapter, different frequency vibrations affect the human body in different ways. If the vibration has a single component or frequency, then vibration amplitude and exposure time characterise the amount of vibration and thus discomfort. Unfortunately, this does not apply to lifts, as stated in the previous chapter.

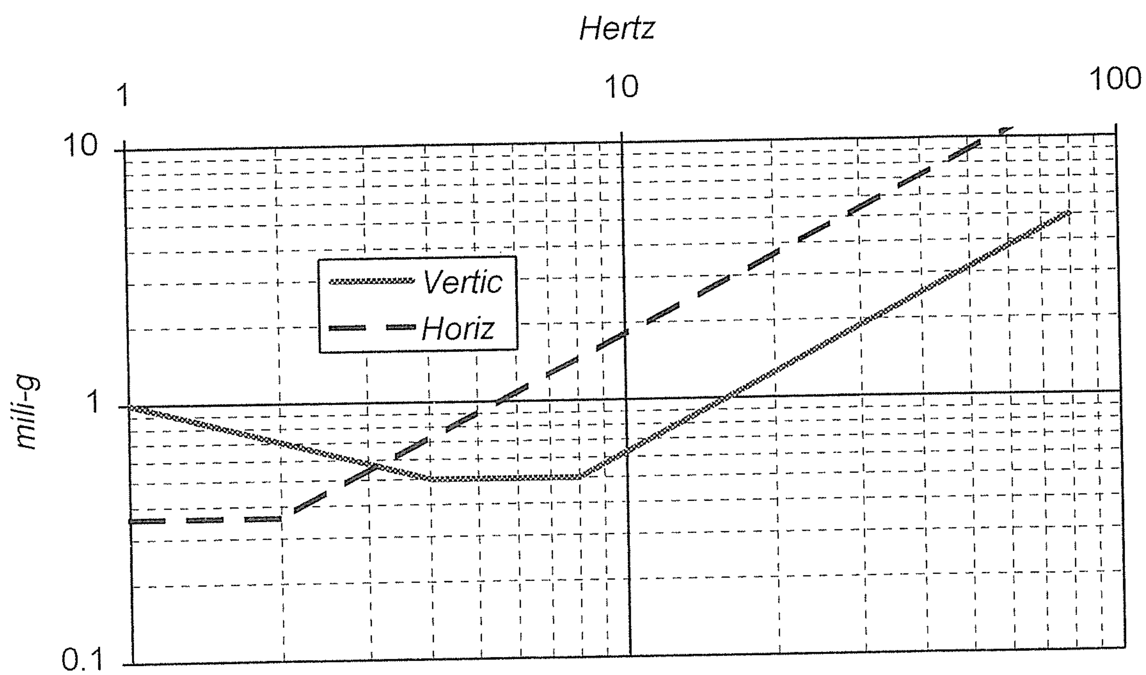

Figure 1: Acceleration base curves defined in ISO 2631 standard part 2

If a broad-band vibration is to be assessed and translated into a single comfort parameter, the way each frequency affects a person's discomfort must be taken into account. ISO 2631 part 2 defines acceleration and velocity curves with respect to vibration frequency. If the vibration level is inferior to those defined in these curves, the users should not feel anything. These curves are lower in the frequency ranges where the human body is more sensitive to vibration, and higher in the ranges where it is less sensitive.Other kinds of curves defined in the first part of this standard and in other standards represent other concepts, such as the amount of vibration a person can withstand for a determined period (exposure limit), or the maximum acceptable level under a defined condition (comfort boundary). Some of these curves depend on vibration time (lower for longer exposure), and also on the degree of discomfort (higher for higher discomfort values). Nevertheless, all curves defined in ISO 2631 having the same profile, any of them can be used as a weighting pattern to assess vibration discomfort.

Figure 1 shows the weighting curves used as a pattern in this job. Different curves are defined for horizontal or vertical (X or Y) vibration. For horizontal vibration, maximum sensitivity occurs in a frequency band ranging from 1 to 2 Hertz, and then decreases until its effect is almost negligible (at frequency 80 Hertz). On the other hand, vertical vibration sensitivity is supposed to increase from 1 to 4 Hertz, becomes maximum between 4 and 8 Hertz, and then decreases until it disappears at frequencies beyond 80 Hertz, as in the horizontal vibration case.

The next step is to match existing vibrations to curves obtained from ISO 2631. This can be done by scaling ISO 2631 frequency pattern until it best fits the pattern obtained from a lift, as seen in the next chapter.

4.2 MATCHING VIBRATION EXPERIMENTAL DATA TO ISO 2631

The first step consists in obtaining the frequency spectra for a lift. This can be achieved by placing a 3D accelerometer on the lift cabin floor and recording the signal on computer. FFT (Fast Fourier Transform) is used to evaluate the contents of that acceleration signal in each frequency of the appropriate frequency range. The spectrum for each of the 3 directions (X, Y and Z) is thus obtained (Figure 2).

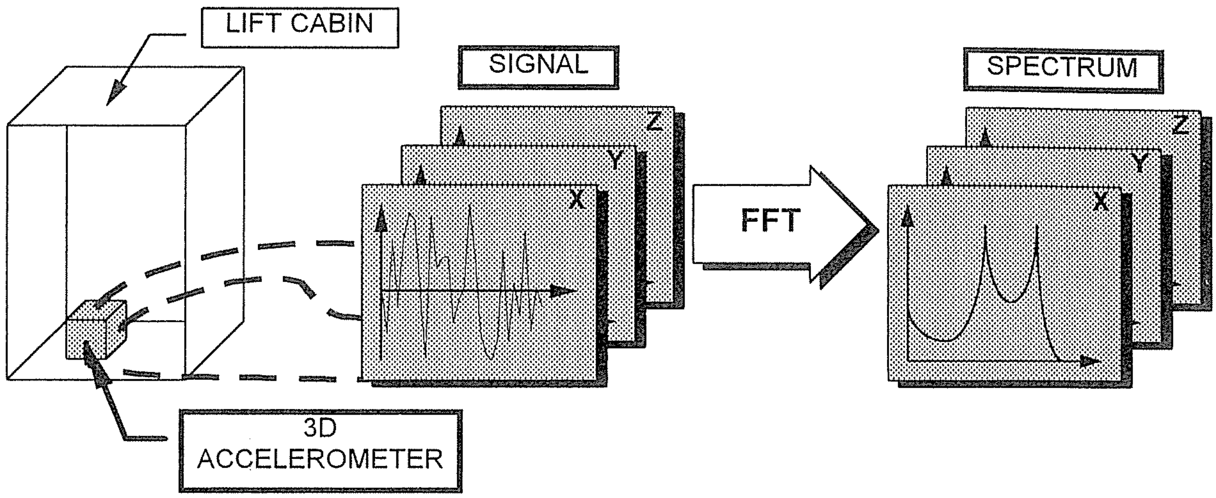

Figure 2: First step. Obtaining X, Y and Z acceleration spectra.

The obtained spectra must be compared to ISO 2631 curves. For this the frequency range is first divided into octave thirds. An octave is a frequency range f_1 to f_2 where $f_2=2f_1$. An octave is composed of three octave thirds, with equal frequency values. Consequently, for an octave third, $f_2=2^{1/3}f_1$. For the obtained spectra, the maximum acceleration value lies inside each octave third, resulting in a set of blocks which "wrap" the spectrum, as seen in figure 3. This wrapping results in a kind of worst mean value along the octave third.

The pattern curve will be the curve defined in ISO 2631 as base curve for accelerations.

The last step to match ISO 2631 curve is scaling curves in figure 1 until they are high enough to just "touch" the 1/3 octave blocks resulting from the measurements. The factor by which the ISO curve has been multiplied to obtain this result will give an idea of the comfort of the installation in each direction, and can be used as a single comfort parameter. From now on, this factor wil be referred to as ***k***.

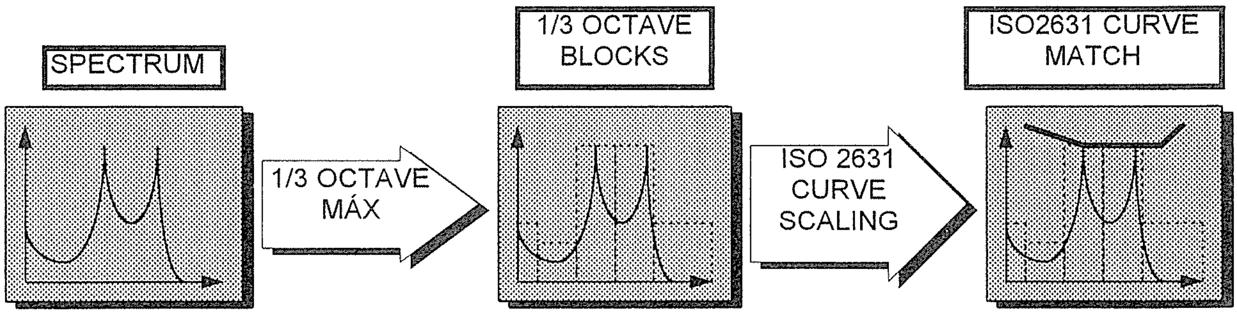

Figure 3: Second step. Matching spectra to ISO 2631 scaled curve

The method just shown can be broadly used provided that crest factors for vibrations do not exceed a value of 6 and taking in account that noise has not been considered.

4.3 ACCEPTABLE K LEVELS

Although a way to obtain parameter ***k*** that accounts for the comfort of a lift installation has been stated, comfort levels have not yet been defined. Since comfort or discomfort are subjective concepts, there is no "standard" way to state which are acceptable *k* levels. ORONA has tested a broad number of installations and subjectively classified them by their degree of comfort, at the same time measuring their *k* level. This gives an idea of which *k* levels can be considered acceptable for a comfortable installation. Figure 4 shows the three curves for horizontal vibration on a typical installation.

However, not every installation can be considered comfortable at the same vibration levels. It seems logical that luxury installations should be allowed lower vibration levels than less costly ones. Thus, ORONA has set different *k* levels for different kinds of installations.

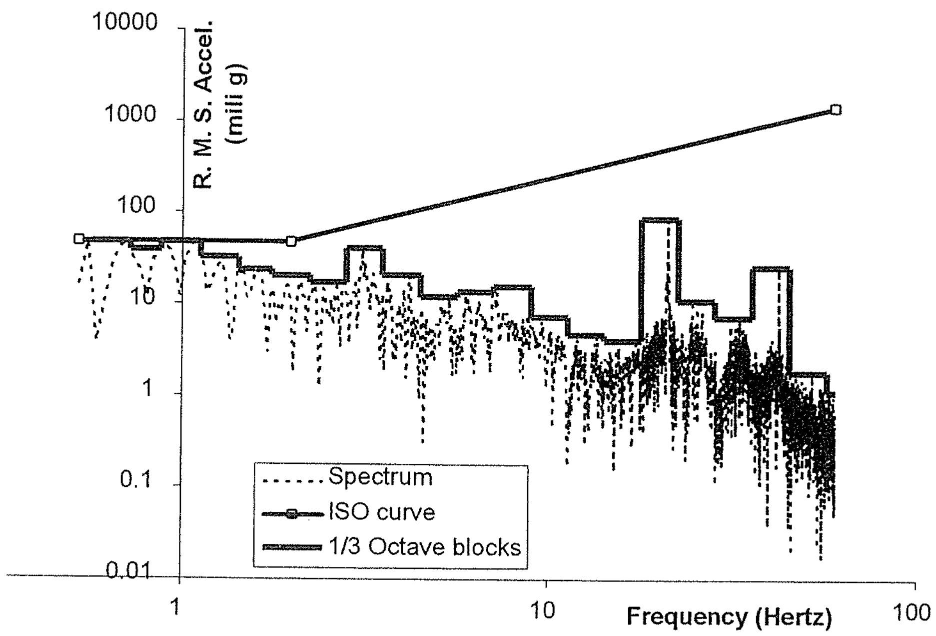

Figure 4: Example of comfort evaluation in X direction

4.4 OTHER COMFORT STANDARDS

Although the method presented here is well suited for comfort analysis, other standards and methods for evaluating comfort have been set up by different authors. The one specified in British Standard 6841 is especially interesting, and an explanation for its fundamentals can be found in Griffin (1994). The method found in this standard is based on studies conducted by the Institute of Sound and Vibration Research (ISVR), and is based on more up-to-date research than the one sustaining ISO 2631.

BS 6841 proposes a different way of weighting vibration at different frequencies, and extends the frequency limits beyond the ones proposed by ISO 2631, especially at low frequencies. It gives 12 possible axes for measuring vibration: six on the seat (supposing the passenger is seated), three for the back, and three for the feet. Once vibration at these axes has been evaluated using the weighting patterns, a single comfort parameter can be obtained, averaging all the axes.

Nevertheless, in the case of lifts, the axis should be greatly reduced; a possibility that is mentioned by Griffin himself. The use of a single comfort parameter for every direction is also questionnable in the case of lifts, since vibration in vertical and horizontal directions have different meanings, and different measures are often needed to reduce them. Thus, different comfort parameters for different axes give a more precise idea of the installation's status.

5. CONCLUSIONS

In this report, a method has been presented in order to obtain a single parameter for evaluating the comfort of a lift installation.

The method is simple, easy to use, based on international standards and accounts for the subjectivity of the problem, since the limits for the obtained parameter have been fixed comparing the actual value of the parameter to the "feeling" experts get in existing installations.

It is being used on the evaluation of vibration discomfort in a great amount of ORONA's installations, thus enabling the users to gain experience on the understanding of comfort and vibration in lifts. At the same time, the main causes of lift discomfort can be discovered and often solved.

6. BIBLIOGRAPHY

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7. AUTHORS BIOGRAPHY

Aldaia J.M. obtained his Engineeering degree from the University of San Sebastian in 1968. He has worked as a scientist in ORONA S.Coop. in R&D department since 1979 as Mechanical R&D Manager, he has involved in many high technology proyects.

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