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STUDY OF SOUND QUALITY IN REFRIGERATION

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ABSTRACT

In the past, sound design was focused on the minimization of the emitted sound. Understanding that the lower the sound the better. Nowadays, this concept is outdated, considering, in addition to the sound pressure level, many more aspects of the sound to convey emotions to the client. Thus, a new concept called sound quality has emerged to reach more facet of the sound. In refrigeration systems, the recommendations of European Union are aimed at reducing the greenhouse emissions by means of the replacement of the hydrochlorofluorocarbons gases for other less pollutant. In this work, the sound quality of a refrigeration system using two different gases, R-404A and its alternative (R-134A), has been studied.

1. INTRODUCTION

The use of refrigeration is very extending both in domestic applications and industrial processes. The great majority of industrial refrigeration consists on facilities destined to supply the refrigerator demand of refrigerating chambers and cooling tunnels among others. At the beginning of industrial refrigeration, different substances have been used to improve the efficiency of the process, as ammonia (R-717), dioxide of sulphur and dioxide of carbon, which are high toxic gases. For this reason, the researches related to refrigeration have been focused on the development of new alternative refrigerant gases less toxic and harmful to the environment.

Thomas Midgley (Midgley and Henne, 1930) developed the Chlorofluorocarbon gases (CFC) including Freon (R-12). However in the 80's, it was discovered that these gases are one of the main causes of the destruction of the ozone layer and the greenhouse effect, so in 1987 the Montecarlo Treaty was signed, in which the manufacture and the use of these gases are restricted.

Afterwards, Hydrochlorofluorocarbons were included, being less aggressive with the ozone layer (Freon 22 or R-22). This gas was one of main refrigerants used in the refrigeration industry until 2010 in Spain. However, other gases that do not affect the degradation of the ozone layer, eliminating the chlorine atoms of their molecules, and replacing them with hydrogen atoms gave rise to Hydrofluorocarbons (HFCs). These gases include refrigerants as R-134A, R-404A, R-407C or R-410A, which are currently the refrigerants most used in industrial application and scientific community. Recently, European Union (Consejo, 16 de abril de 2014) established the replacement of refrigerant gases (HFC) in industrial freezers and refrigerating chambers with a potential for global warming (PGW) of 2500 in 2020 and of 150 in 2022. In this sense, the choice of the best refrigeration gas involves environmental issues but also efficiency, low energy consumption and low noise emission. Although, there are many studies about the efficiency and gas emissions of the refrigeration gases; there are not much researches on noise emission (Celik and Nsofor, 2011, Han et al., 2011). Whereas, as far as we know, the sound quality in refrigeration using different gases has not studied.

The main aim of this research is the study of sound quality emitted by two refrigeration gases with different PGW as R-134A and R-404A. It is very important as the new regularization establishes the replacement of R-404A by R-134A being thus the noise emission affected by this change of gases. The results of this preliminary study will be extrapolated to predict the noise emission in the University of Córdoba. It is due to there are more than 161 refrigerators in the Campus of Rabanales (University of Córdoba) using R-404A. Therefore, if the level of sound is reduced using R-134A instead of R-404A, it could be said that the annoyance due to noise in the Campus could be also improved.

2. MATERIALS AND METHODS

2.1. REFRIGERATING CHAMBER

A refrigerating chamber with a semi-hermetic compressor model A 0.5 4Y (Frascold) has been used, see Fig. 1. Different operating points of the compressor have been evaluated at different working pressures. Table 1 shows the working pressures of the compressor. The gray area in Table 1 indicates no operation of compressor.

Fig. 1. Refrigerating chamber.

Table 1. Working pressures of the compressor with R-134A.

Min.	0	1	2	3	4	5	6	7	8	9	10
HP* (bar)	10	11.1	11.1	10	10	10	9.9	9.9	11	11.5	10.9
LP* (bar)	1.5	2	1.4	0.3	0.3	0.2	0.3	0.5	1.9	2	0.9

HP* High Pressure; LP* Low Pressure; Gray área

Table 2. Working pressures of the compressor with R-404A.

Min.	0	1	2	3	4	5	6	7	8	9	10
HP* (bar)	21	19	19	19	19	21	21.5	20	20	20	20
LP* (bar)	2	0.1	0	0	0	4.5	1	0.5	0.1	0.1	0.1

HP* High Pressure; LP* Low Pressure; Gray área

2.2. MEASURING SYSTEM

Soundbook™ universal portable measuring system with SAMURAI v2.6 software from SINUS Messtechnik GmbH and the Toughbook™ CF-19 were used to acoustic data record of refrigerator with the aid of a microphone. The microphone was placed at 1 m distance from the block of compressor to measure continuous equivalent sound pressure level (LAeqT), see Fig. 2.

Fig. 2. Measurement of noise.

2.3. SOUND QUALITY METRICS

Psychoacoustics indicators constitute an interesting way to measure how nice or disturbing is a sound for human beings. Evaluation of perceived sound is carried out by a jury testing, where members classify sounds according to listener reaction. The number of indicators to objectively classify the sound quality is huge, some of them are loudness, sharpness, roughness, boom, fluctuation strength and tonality. Some metrics, like loudness, are defined following international standards; but this is not common. The selection of a metric to define sound quality depends on the application, but sometimes there are some discrepancies among researchers. This is the case of engine sound quality. Some researchers prefer the

use of loudness, roughness and sharpness indicators in car applications (Redel-Macias et al., 2012, Lara et al., 2015). Loudness provides a subjective measure of the sound energy content and its unit of measurement is sone. Measure of roughness is more complex than loudness, as it involves the subjective perception of a sound rapid frequency modulation. It is measured is asper. The high frequency content of a sound is measured by sharpness metric; its measure unit being acum.
After registering the continuous equivalent sound pressure level, loudness, roughness and sharpness have been calculated using Matlab R2016b (version 9.1).

3. RESULTS

Table 3 and 4 shows the results of total loudness, roughness and sharpness for both refrigerant gasses. Spectrograms of Sound Pressure Level for both refrigerant gasses (R-404A and R-134A) are described in Figs. 4 and 5, respectively.

Table 3. Sound quality metrics for R-134A.

	Loudness (Sone)	Roughness (Asper)	Sharpness (Acum)
1	65.058	0.128	5.210
2	58.193	0.129	4.622
3	60.959	0.113	4.768
4	52.363	0.087	3.300
5	88.208	0.115	5.037
6	63.108	0.097	5.087
7	58.818	0.123	4.712
8	67.367	0.128	4.584

Table 4. Sound quality metrics for R-404A.

	Loudness (Sone)	Roughness (Asper)	Sharpness (Acum)
1	81.199	0.332	5. 572
2	62.985	0.447	5.119
3	62.941	0.417	5.139
4	53.546	0.091	3. 481
5	100.229	0.298	6.157
6	75.220	0.301	5.213
7	59.952	0.411	5.291
8	57.183	0.367	5.391

4. DISCUSSION

As can be seen in Tables 1 and 2 respectively, total loudness, roughness and sharpness of R-134A are reduced with the use of R-404A. For some working pressure points, the different achieved is greater than 20%. It could be possible to the working pressures are significantly lower with the use of R-134A. Although the reduction is generalized for all range of pressures, it can be observed that the lower frequencies, the higher reduction. In summary, the replacement of R-404A for R-134A improves the sound quality. As mentioned above, it can be due to the difference between operating pressures.

5. CONCLUSIONS

This works is focused on the study of sound quality for two refrigeration gases, R-404A and R-134A. The results have revealed that the sound quality is improved with the replace of R-134A as its working pressures are lower than R-404A. Therefore, it could be said that the replace of a gases for other could reduce the overall noise and improvement the sound quality in the Campus of Rabanales at University of Córdoba.

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