FORECAST ACOUSTICS FOR INDUSTRIAL AND ENVIRONMENTAL NOISE CONTROL

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Abstract. *The work environment may offer safety and conditions to the employees that won't harm their health. The 15th Regulatory Rule of Medicine and Safety Work sets limits for noise exposition according to the working time. Generally, the equipments in an industry plant generate higher noise levels than the allowed by law. Simulations were performed using the computer software developed and validated by the Laboratory of Acoustics and Vibration (LAV) of the Mechanic Engineering School (FEMEC) at Federal University of Uberlândia (UFU). The analysis and mitigation of the noise were simulated in a pretending industrial area composed of one compressor (induction motor, rotation amplifier and a compressor) installed in a shed and an industrial fan (fan and an electric motor). A sensitivity analysis was performed and it was checked that the most important contribution to increase the noise levels came from the compressor. Four different acoustic solutions were studied and simulated (the installation of an acoustic barrier in front of the compressor, the installation of an enclosure around the noise source, the installation of a steel gate in the entrance of the shed and the use of ear protectors by employees). Analyzing the results, it was found out that the enclosure reduced the noise level in the area .However the material Isoseal® used to simulate the enclosure makes the solution very expensive because that's a high-tech material. The installation of the acoustic barriers was not effective, since the compressor noise level remains at the same levels in the simulated area. In the shed's neighborhood the noise could be reduced closing the entrance with the steel gate. However, the reverberant field inside the shed increased, not allowing to be used by the employees, even wearing ear protectors. The studied cases show that when the employees were inside the shed although wearing ear protectors they were exposed to high noise levels. Based on the performed simulations, one concludes that the compressor enclosure best acoustic solution to the problem*

Keywords*: Acoustics, Noise Control, Safety Work*

1. INTRODUCTION

In an industrial area, the work environment must offer to its employee's safety and conditions that will not harm their health. The Sound Pressure Level (SPL) that they are exposed is a factor to be considered. The Brazilian 15th Regulatory Rule of Medicine and Safety Work sets limits of noise exposure for specified working time. Generally, the equipments in an industry plant generate higher noise levels than the allowed, making necessary an acoustic treatment. This work exemplifies the methodology used by the Laboratory of Acoustics and Vibration (LAV) of the Mechanic Engineering School of the Federal University of Uberlandia, for the analysis and mitigation of the noise of industrial equipments.

2. OBJECTIVE

The application of noise control techniques through acoustics treatments in order to mitigate the noise levels generated by the equipments in an industrial plant.

3. METHODOLOGY

To analyze the noise levels in the area simulations are performed using the computer software developed by LAV. The modeling of the simulations was based on the Ray Tracing Theory (Gerges, S. N. Y.) – with a scan of 10 degrees in 10 – and considering monopolar sound sources. Some of the limitations of this method are the calculation time, the complexity of the 3D model to be used – this factor can increase exponentially the calculation time, and the difficult to implement diffuse reflections in the software. The simulations take into account the existing sound barriers in the neighbor of the sources considering the contents of Duarte, J. B.; CONEM 2008. The software is already validated in other works developed by LAV. The analysis was performed in a layout using CAD software. The sources are identified and positioned in this 3D layout.

The schematic drawing is showed in the Fig. 1. To simulate an industrial plant, it was choose two different equipments: an industrial fan and a compressor. The first was positioned in front of the shed, which is the blue box in Fig. 1, and the compressor was inside the shed.

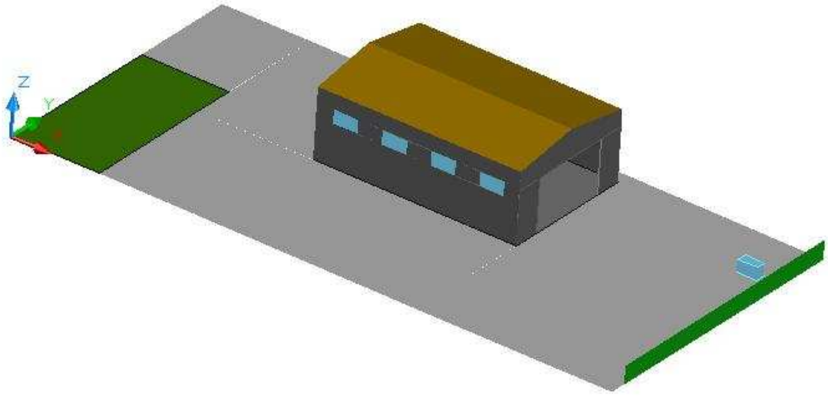

Figure 1. The 3D Layout for the simulated industrial plant.

It's necessary to know the Sound Power Level (SWL) of the equipments in one octave band to perform the simulations. In this work, it was used real SWL from the data bank of LAV, so that the simulations were very close to a real situation. It's important to emphasize that the equipments don't work alone. It's necessary an induction motor and a rotation amplifier, so that the compressor can operate, and all this equipments generate noise. The fan, to work, requires only an electric motor. The values of SWL of each component are specified in Tab. 1.

Table 1. Sound Power Level (SWL in dB) of the equipments in one octave band.

Octave Band (Hz)	63	125	250	500	1000	2000	4000	8000
Compressor	100	99	97	97	99	103	102	98
Compressor Motor	96	98	98	98	98	98	95	88
Rotation Amplifier	106.1	109.7	109.7	109.7	109.7	109.7	109.7	109.7
Fan's Electric Motor	62.5	65.5	67.5	70.5	70.5	69.5	64.5	56.5

The SWL values of the fan were showed separately, because it was found out that its noise was directional, in other words, the fan Sound Pressure Level were higher in some directions. In this way, it was necessary to specify its directivity in the used software for simulations. The identified Sound Power Level's are specified in Tab.2 and Tab. 3, respectively.

Table 2. Sound Power Level of the fan in one octave band.

Octave Band (Hz)	63	125	250	500	1000	2000	4000	8000
Fan (dB)	102	96	93	95	91	92	81	74

Table 3. Fan Directivity Values.

Teta_i	0°	22,5°	67,5°	112,5°	157,5°	202,5°	247,5°	292,5°
Teta_f	22,5°	67,5°	112,5°	157,5°	202,5°	247,5°	292,5°	337,5°
Fi_i	-85°	-85°	-85°	-85°	-85°	-85°	-85°	-85°
Fi_f	90°	90°	90°	90°	90°	90°	90°	90°
DI (dB)	-18	-16	-14	-12	0	-11	-14	-16

The angles values: Teta_i, Teta_f, Fi_i and Fi_f are showed in the Fig. 2. The DI values in dB that should be subtracted from the SWL in the respective directions. The angle reference is the same from the Cartesian plane.

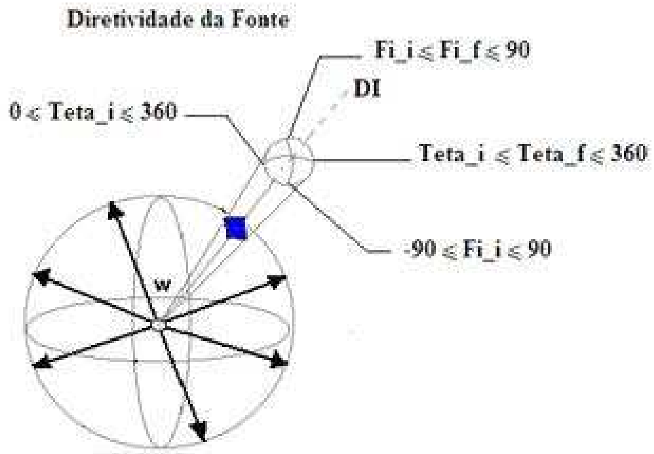

Figure 2. The angle specification in Tab. 3.

The software produces as results an equivalent mapping (isocurves) of sound pressure level for the analyzed area in a plane 1.6 m height from the floor. With this simulated results (Sound Pressure Level – Isocurves and Percentage Histogram of exposure by area) it was verified the necessity of an acoustic solution to mitigate the high levels of noise. Thus, a sensibility analysis was performed, and the sources that contribute for the high noise levels were identified. Therefore, with the critical sources identified the proposed acoustical solutions can then be simulated, and their effectiveness can be verified. The software uses the statistics information presented in Bies (2003) for the approximation of the treatments.

4. RESULTS

All the simulation maps show the top view of the area and the estimated SPL at 1.6 m high from the floor (which is the mean height of a human being). The accumulated histogram is the area percentage under the specified SPL level.

The simulated results for Sound Pressure Level (Isocurves) and Accumulated Histogram are shown in Fig. 3 and Fig. 4, respectively. The black areas in Fig. 3 mean SPL higher than 100 dB(A).

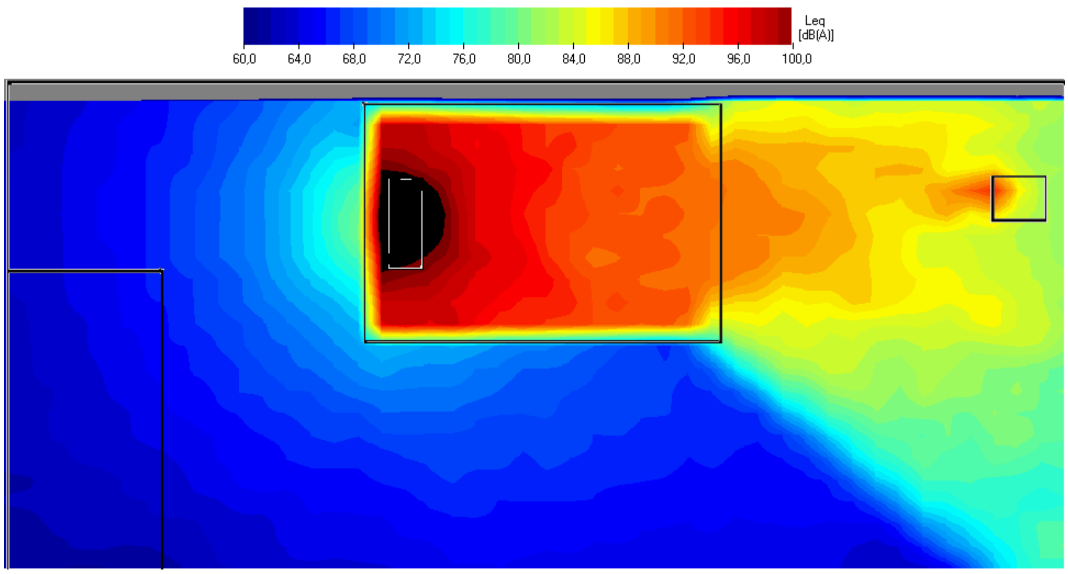

Figure 3. Sound Pressure Level – Isocurves for the simulated area.

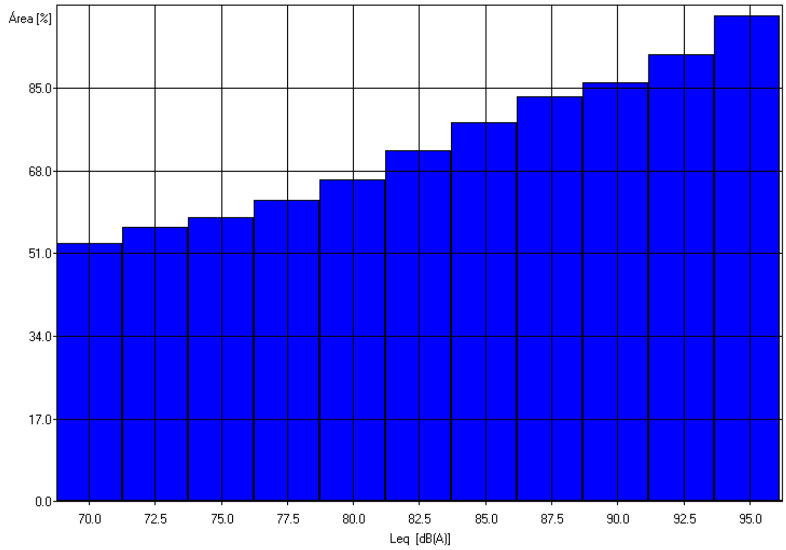

Figure 4. Accumulated histogram of percentage area under specific Sound Pressure Level.

From Fig. 3 and Fig. 4, one can notice that approximately 28% of the area was exposed to higher noise levels than the allowed (85 dB(A) for 8 hours of work).

In the area nearby the compressor set (induction motor, rotation amplifier and compressor) were estimated SPL higher than 100 dB(A). Therefore, by the regulation this area requires acoustic treatment to mitigate the noise level, since the actual level could cause hearing problems to the collaborators.

Doing a sensitivity analysis we can identify which equipment needs an acoustic treatment. This analysis consists of virtually turn on and turn off each source and analyze the effect in the total SPL (70, 80, 85, 90 e 95 dB(A)) in the studied area. Tab. 4 shows the sensitivity analysis results.

Table 4. Sensitivity analysis results.

Situation	SPL (dB)					
	70	75	80	85	90	95
	Area (%)					
Compressor turned off	77,2	93,9	98,1	99,5	99,7	99,9
Fan turned off	55,1	60,5	68,8	81,1	86,9	98,1
Current Situation	55,2	60,5	70,2	80,4	87,3	98,0

From Tab. 4, one can see that there was no significant reduction in the exposed area to high SPL when the fan was turned off. But, with the compressor turned off the majority of the exposed area is below the allowed SPL noise level.

Thus, the compressor was identified as the critical equipment that needs acoustic treatment.

The first proposed solution was the installation of an acoustic barrier in front of the compressor set. In this case, a wall made of an acoustic material is positioned in front of the equipment not to allow the sound to propagate in the industrial area. The material used for the barrier is called Isoseal®, and its properties are specified in Tab. 5.

Table 5. Acoustic Absorption and Transmission Loss (dB) by octave band of Isoseal® (Provided by the manufacturer).

Frequencies (Hz)	125	250	500	1000	2000	4000	NRC
Absorption	0,12	0,47	0,85	0,84	0,64	0,62	0,70
Transmission Loss	11	16	24	30	35	35	27

The software developed at the LAV has an option of acoustic treatment which allows the specification of an acoustic barrier (2,0x2,5 m²). Thus, the simulated results of the Sound Pressure Level – Isocurves are shown in Fig. 6. The grey area means that the SPL was below 60 dB(A). The accumulated histograms of the initial condition and simulated acoustic treatment are presented in Fig. 7. The Barrier's position is showed in Fig. 5.

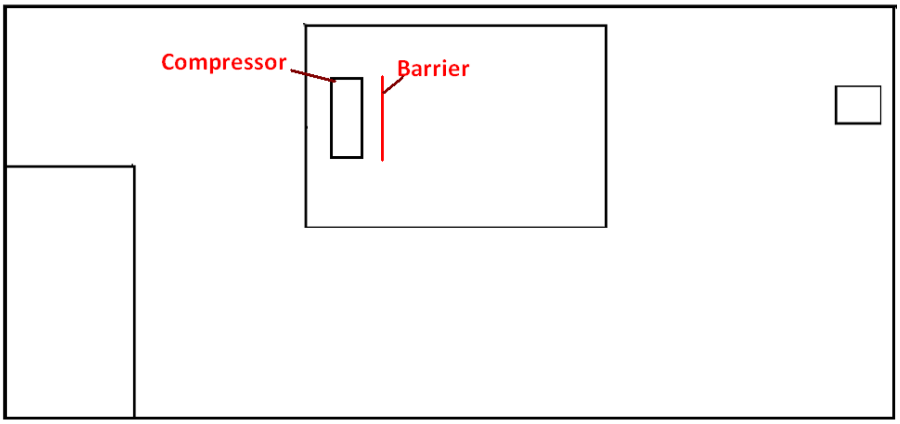

Figure 5. Barrier's position.

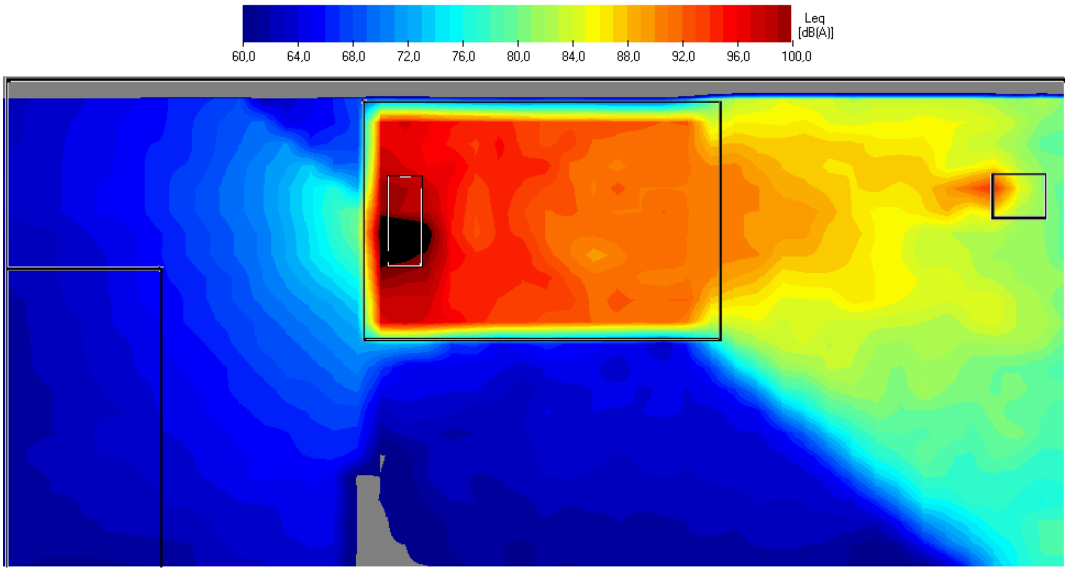

Figure 6. Sound Pressure Level - Isocurves for an acoustic barrier in front of the compressor set.

From the Fig. 6, it was possible to verify that the SPL exposure was still high, not being allowed the presence of the employees in the area. The barrier is not effective, since it was installed inside a closed room, making the sound reach the whole area through reflections trough the roof.

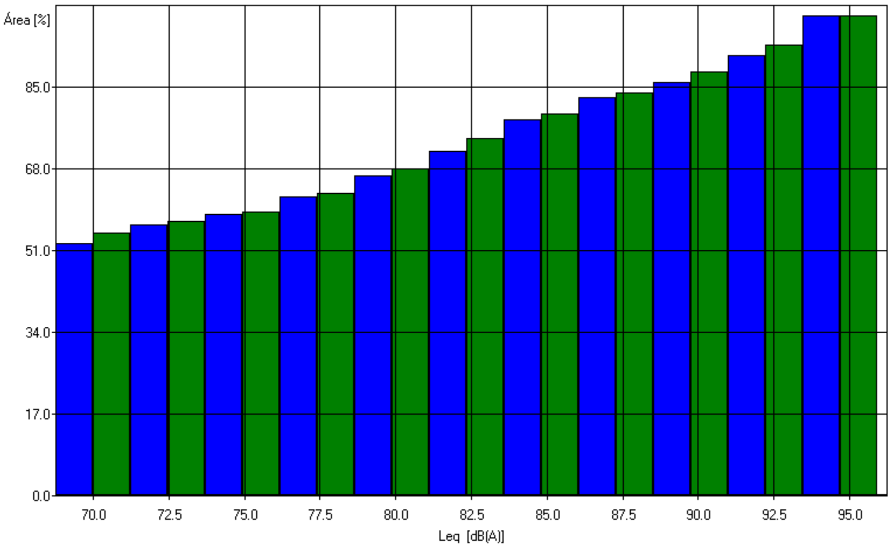

Figure 7. Accumulated Histogram: comparing the initial situation (blue) and the acoustic treatment - barrier (green).

The histogram shown in Fig. 6 shows that there was not enough attenuation to make the area appropriated for an 8 hours working time.

The second proposed solution was the installation of an enclosure (1,5x2,0x2,5 m³) on the compressor set. The enclosure position is showed in Fig. 8. This solution consists in cover all the equipment with a material that has high transmission loss, so that the noise will not be able to get out the enclosure. The material that was used was the same used in the barrier.

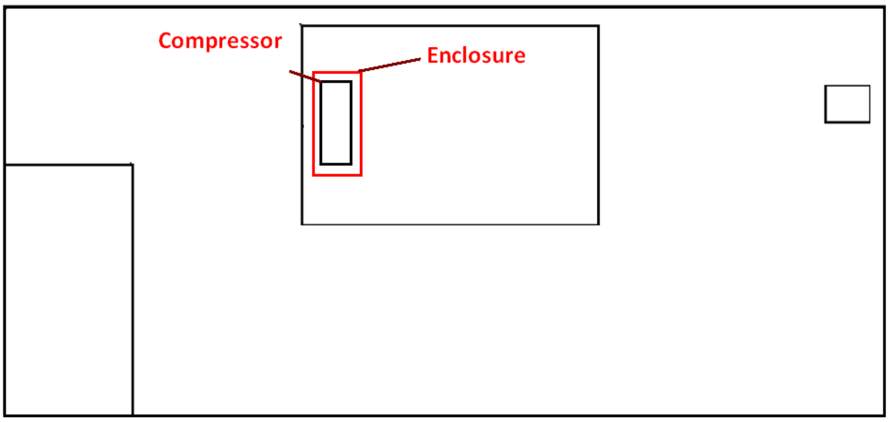

Figure 8. The position of the enclosure.

The simulated results of the Sound Pressure Level – Isocurves are shown in Fig. 9. The grey area means that the SPL was below 60 dB(A). The accumulated histograms of the initial condition and simulated acoustic treatment are presented in Fig. 10.

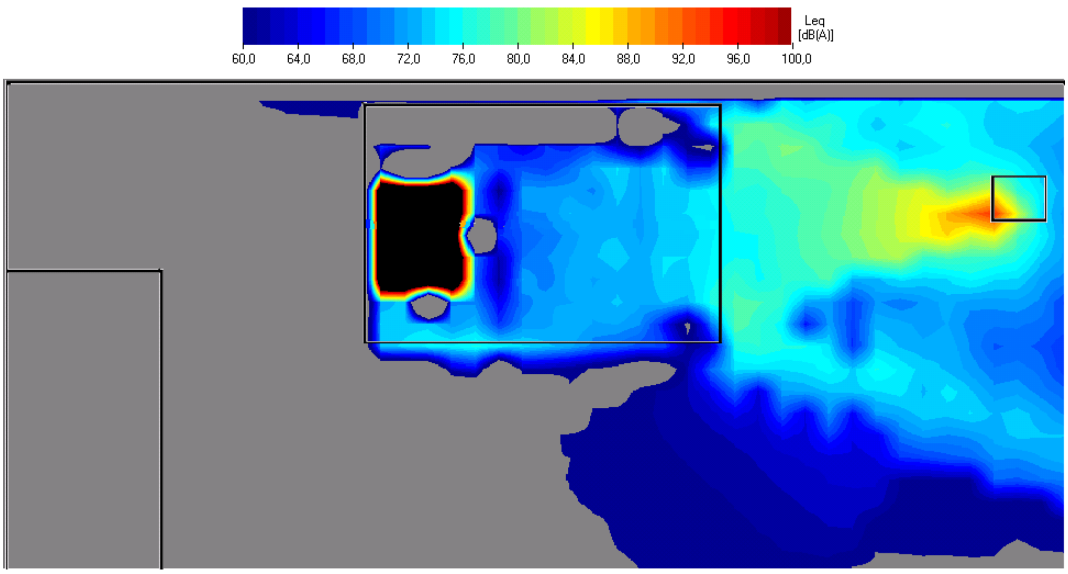

Figure 9. Sound Pressure Level - Isocurves for an enclosure at the compressor set..

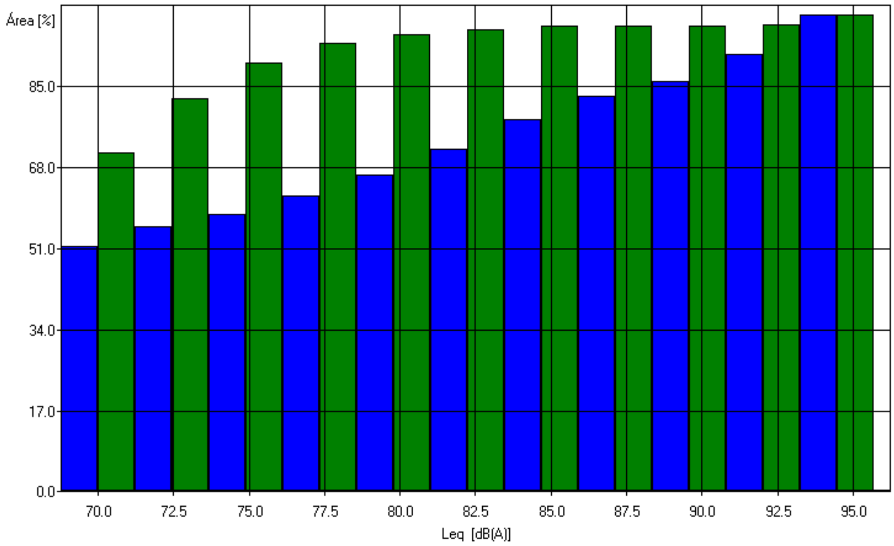

Figure 10. Accumulated Histogram comparing: the initial situation (blue) and the acoustic treatment – enclosure (green).

Analyzing the Fig. 9 and Fig. 10, it was observed that the installation of the enclosure was very effective for the treated equipment, verifying an increase of approximately 20, 32, 22 and 19% of the exposed area under the noise levels of 70, 75, 80, and 85 dB(A), respectively

The third proposed solution is the installation of a steel gate in front of the shed. The Fig. 11 shows the layout in perspective of the area with the gate installed.

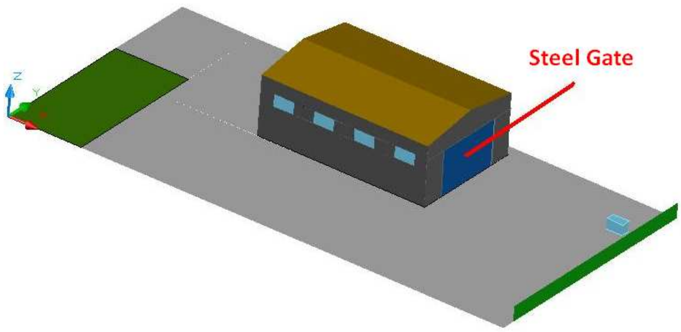

Figure 11. Analysed area with the installation of the steel gate.

In Fig. 12 is showed the Sound Pressure Level - Isocurves simulated, LAeq (dB(A)). The Accumulated Histogram is showed by the Fig. 13.

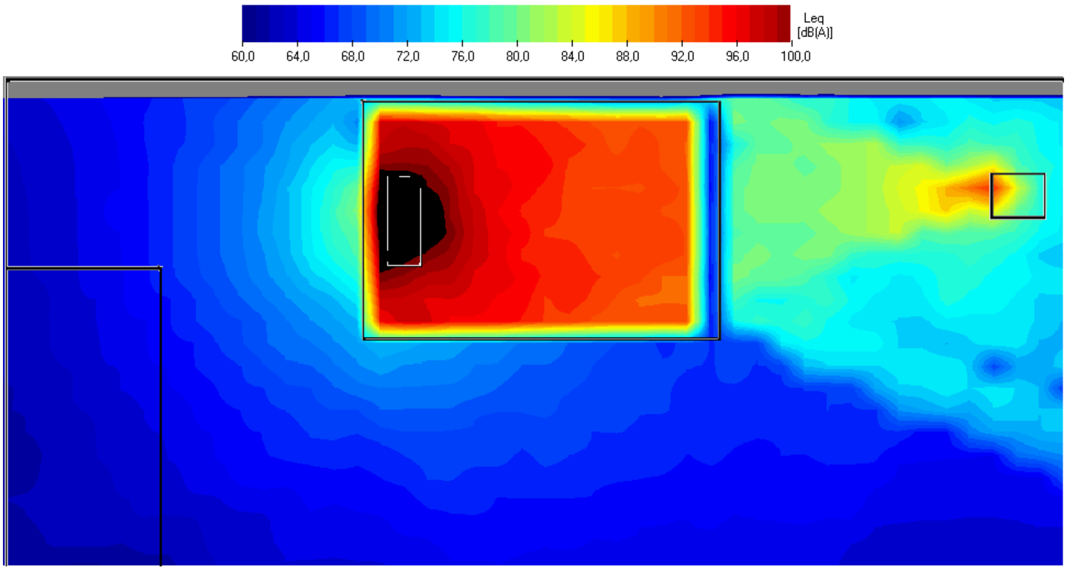

Figure 12. Sound Pressure Level - Isocurves simulated for the area with the installation of the steel gate.

Through the analysis of the Fig. 12 and Fig. 13, it was found out that the percentage of exposed area to high noise levels also decrease. But inside the shed, the reverberant field increase, and it was observed that the SPL ranges between 92 dB(A) and 103 dB(A). That meaning, the employees are not allowed into the plant area, even wearing ear protectors.

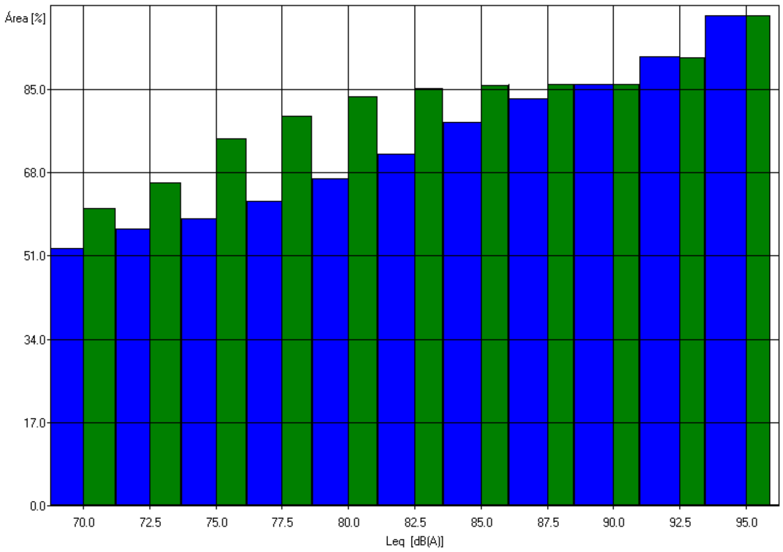

Figure 13. Accumulated Histogram comparing the current situation (blue) and the situation with the steel gate installed (green).

The last proposed solution was the use of the ear protectors. Fig. 14 shows the simulated Sound Pressure Level - Isocurves, LAeq (dB(A)) for this situation. The accumulated histograms are showed in Fig. 15. Tab. 6 shows the attenuation levels (AT), and the respective standard deviation (σ), of the ear protector of pre-molded insertion type - POMP. For the simulations, it was subtracted 10 dB of the attenuation levels provided by the authors due to some practical considerations.

Table 6. Mean Attenuation (AT), and the respective Standard Attenuation (σ) of the ear protector POMP.

	Central Frequencies (Hz)						
	125	250	500	1000	2000	4000	8000
AT (dB)	8,2	10,7	22,3	11,1	15,8	16,9	35,6
σ	8,9	8,9	8,2	7,4	7,8	8	11

With this forth solution, it was verified that outside the shed, the noise levels will not harm the employees. But inside the shed, the employees will still be exposed to levels that ranges from 86 dB(A) to 98 dB(A). Therefore, it is not an allowed place to 8 hours of working time.

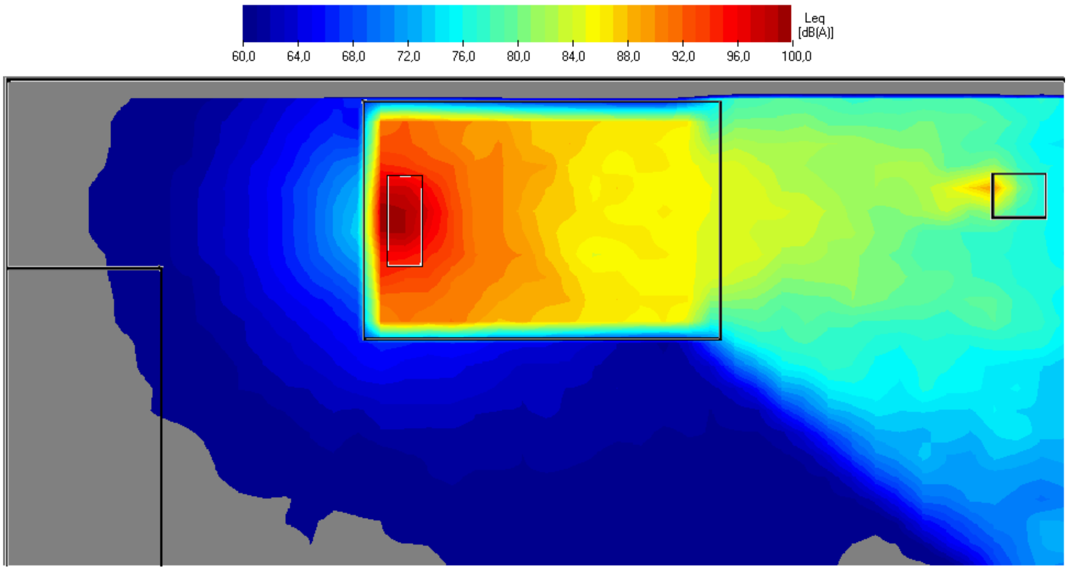

Figure 14. Sound Pressure Level - Isocurves simulated for the area with the utilization of the ear protectors.

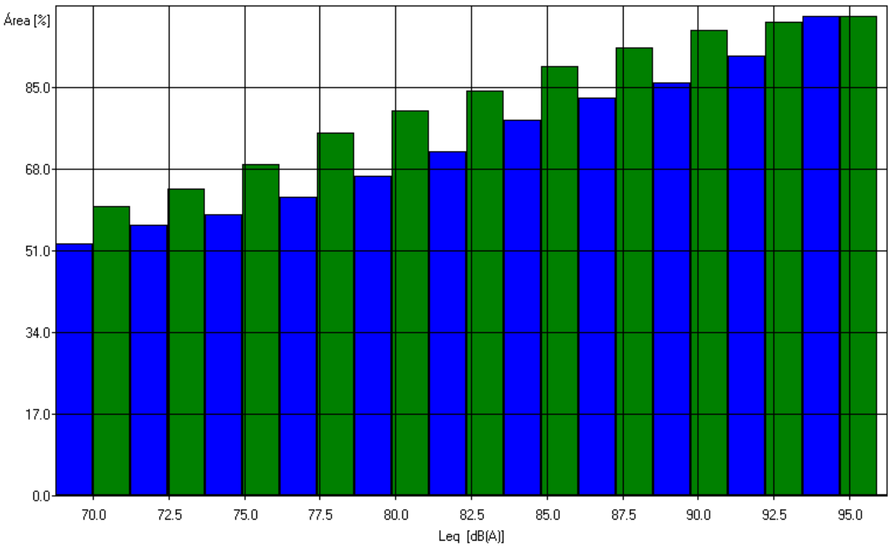

Figure 15. Accumulated Histogram comparing: the initial situation (blue) and the acoustic treatment – ear protectors (green).

5. CONCLUSIONS

It was performed simulations using the software developed and validated by LAV in previous works, for the analysis and mitigation of the noise in a pretending industrial area composed of a compressor set (induction motor, rotation amplifier and compressor) installed in a shed and an industrial fan (fan and electric motor).

A sensibility analysis was made and it was found out that the compressor was the critical equipment in the studied area.

From the results of the simulated solutions (installation of an acoustic barrier in front of the compressor, installation of enclosure in the same equipment, installation of an steel gate in front of the shed and the use of ear protectors), it was concluded that the installation of the gate was not enough. The reverberant field inside the shed was increased, not allowing the permanence of employees, even using ear protectors. This procedure would be appropriated for the reduction of the noise levels in the shed neighbor.

The wearing of the ear protectors was considered inefficient, since the collaborators will still be exposed to high noise levels inside the shed. But it would not be enough, because it would not reduce satisfactorily the noise levels around the compressor set. The installation of the barrier was not effective, because the reflection of the sound on the roof of the shed helps the sound to achieve the area even with the barrier in front of the equipment, making the solution not appropriated.

Analyzing the effect of the installation of the enclosure, it was verified that it reduces the noise level around the equipment, with the noise levels ranging from 60 dB(A) up to 70 dB(A), but this option is very expensive. The material used in the simulations of the installation of the enclosure was the Isoseal®, which is a high technological material, and that can burden the project cost.

6. ACKNOWLEDGEMENTS

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