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Reduction through Brick Wall Barrier and Acoustic Sponge of Environmental Noise Levels from Chiller Cooling System

Fatih TUFANER*[1,2]

Abstract

The aim of this study was to investigate the noise level reduction of the air cooled liquid chiller to the desired levels of environmental noise requisite. Noise control procedures are implemented with various systems to prevent environmental noise disturbances. This paper examines the application of a passive noise control approach to the control of air-cooled liquid chiller noise located in the garden of an official institution. The approach of passive noise control utilizing brick walls with acoustic sponge in the immediate vicinity of the chiller is discussed. When the chiller was covered with a brick wall, the noise level was reduced by 5.5 Leq dBA 1 m away from the nearest residence. However, this reduction could not meet the requirements of legal regulations. Therefore, the inside of brick wall was covered with acoustic sponge. As a result, the ambient noise level where 1m away from the nearest residence to the chiller has been reduced to the background noise levels with a total reduction of about 8.5 Leq dBA. It is shown that, due to the noise produced by the chiller fans and compressors, so as to achieve significantly cognizable levels of noise reduction it is necessary to isolation brick walls with acoustic sponge.

Keywords: Noise control, reduction, chiller, barrier, acoustic sponge

1. INTRODUCTION

In the past, general city noise was perceived as a city negativity that had to be accepted. However, today, with the technological developments in many areas, the types of complaints subject to noise have increased. In addition to that, necessary arrangements have been made with the laws and regulations regarding the issue of noise. As a result, the people of the city have understood that the noise is not a compulsory disorder and it can be eliminated with the necessary measures.

Especially recently, noise complaints of mechanical equipment that meet the cooling requirement such as chiller has become an important problem in city settlements. These systems are quite large and cause noise disturbance and cannot be completely isolated from their environment due to their technical requirements. Therefore, these systems need a

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special noise control. When the literature studies are examined, it is seen that there is a big literature gap in this regard. In most studies, there are passive and active noise control studies [1-7] for different systems producing noise. However, there are very few limited scale studies [8-11] for huge systems such as a chiller or electric generator. Therefore, in the present study, a noise control method has been investigated for the chiller cooling system that produces high noise at different frequencies.

Noise control operation should be started with the design of the facility to be made. It is generally recommended to reduce noise by engineering studies. However, generally, noise reduction efforts are started with noise complaints from the environment and are attempted by those responsible for the unit where noise occurs. Their applications generally involve the following: placing the noise source on a flexible surface; completely shut off the noisy machine; adding acoustic insulation materials to the room where the machine is located, and building a barrier between the noise source and the complainants. Installing an acoustical enclosure or barriers around the noise source usually accomplishes the reduction of airborne noise. However, it is impractical to completely enclose the noise source with an acoustic enclosure for cooling the noise source and providing other environmental requirements. In fact, completely enclosing the noise source will require the installation of an auxiliary cooling system. Indeed, industrial fans that provide the necessary air movement produce noise nearly as intense as the noise source produces. Therefore, it is not practical to completely enclosing the noise source [8].

Cooling systems such as air-cooled liquid chillers and other noisy sources are affecting noise sensitive receivers in the nearest buildings and areas. It is more difficult to guarantee a good sound environment near the dwellings and especially in the case of open windows [12]. Airborne noise control is integral to building the design and construction of indoor and outdoor as well as effective environmental management and operations.

Passive noise control is an effective way to bring environmental noise levels to appropriate conditions by adding appropriate intermediate materials or revising noise-generating systems. Noise barriers are the most effective way to reduce the roadway, railway, and industrial noise sources as well as noise control in the source [13]. Passive noise attenuation performance depends on the barrier specification. Some materials of the barrier have the ability to absorb the sound energy while some material of barrier can reflect them. Noise barriers are specifically is effective to attenuate the high-frequencies noise [14]. Also, they are particularly effective at close distances where the acoustic shadow zone is formed. The noise reduction function of the barrier decreases as the distance between the noise source or the receiver and the barrier increase [15]. Insertion loss (IL) due to a barrier is also strongly influenced by the type of ground, atmospheric turbulence and the structural features of the barrier [16-18]. In some studies, the inner face of the barriers is covered with acoustic material for better sound insulation [19-21]. Acoustic sponges are a good sound absorber due to their cavity and pore structures and open porosity [22]. Porous materials have been commonly used in numerous industrial fields to absorb sound energy [23]. Especially, in the automobiles, polyurethane acoustic sponges are applied for sound-absorbing materials in order to absorb sounds in the frequency range higher than 1600 Hz [24].

The noise level transmitted from sources such as the cooling fan, air conditioner, etc. in existing structures, inside or outside the building to noise-sensitive uses cannot exceed the background noise level more than 5 Leq dBA [25]. According to the World Health Organization (WHO) and Turkey Regulation for Assessment and Management of Environmental Noise (Çevresel Gürültünün Değerlendirilmesi ve Yönetimi Yönetmeliği (ÇGDY)) guideline, different noise levels have different influences on the dwellings near the chiller. Noise bigger than limit noise levels is a serious annoyance for dwellings in the daytime. Table 1 shows the maximum permissible noise levels for a residential environment [25, 26].

Table 1. Maximum permissible noise levels for residential environments by the WHO and the ÇGDY [25, 26]

Guideline	Specific environment and category	Leq dB(A)
WHO guideline values for community noise in specific environments	**Outdoor living area**	
	Serious annoyance, daytime and evening	55 (16 hours)
	Moderate annoyance, daytime and evening	50 (16 hours)
Turkey ÇGDY guideline noise limit values for specific environments	**Areas with mix use, usually dwellings**	
	Traffic noise, daytime (Existing roads)	68 (12 hours)
	Industrial noise, daytime (Among the areas where commercial buildings and noise-sensitive uses are together, the areas where houses are densely located)	65 (12 hours)

The noise of the chiller systems consists of a combination of the noise of different types of chiller units. Examples include the noise from refrigeration compressor, mechanical fans, and airflow through equipment. All of these noises are composite of many different and separate frequencies of sound that defined the number of vibrations per second and specified as Hertz [Hz]. Pure-tone sounds are more annoying than random broadband sounds in the human ear. Considering the equal dB sound level from random broadband and pure-tone sound sources, pure-tone noise is more likely to cause a noise complaint [10]. In general, to test for the presence of a dominant frequency spectrum component (tone), the sound pressure level in the 1/1 and 1/3 octave band is typically compared to the sound pressure levels on both sides and must pass both of them with a certain level difference (15 dB at low frequencies from 25 to 125 Hz, 8 dB at medium frequencies from 160 to 400 Hz, 5 dB at high frequencies from 500 to 10000 Hz) [27-29].

In this paper, the application of passive noise control to attenuation of the noise produced by an air-cooled liquid chiller was investigated in order to provide the desired levels of environmental noise requisite. In the study, the performance of a gradually constructed acoustical barrier which is designed as a semi-enclosure to reduce the noise of the air-cooled liquid chiller has been evaluated. Concerns about noise conditions and control, design, construction, and operations have been discussed with reference to the ÇGDY (2002/49/EC).

There are few studies in the literature that focus on reducing the noise of huge mechanical systems such as chillers. Therefore, this study is a pioneering field study that performs noise reduction with passive method (brick wall and acoustic sponge). While this paper is a guide in reducing noise caused by mechanical devices such as chiller, it provides a perspective on the level of noise that can be reduced in such problems.

2. METHOD

2.1. General characteristics and location of the air-cooled liquid chillers

The cooling of the official institution is provided by two chillers (YORK R-134a /YVAA0273D) (Figure 1) operating alternately. Its overall dimensions are 2403x2242x8514 mm (HxWxL). The chiller configuration is equipped with high airflow fans with variable speed. Chiller fans give vertical air release from expanded openings. Chillers have been installed on a raised concrete floor about 30 cm to avoid noise and vibration transmission. The chillers have been tied to the main building foundation with a deflection isolator as operational noise will telegraph. The side of the chillers facing the street has been surrounded by a wall with about 2.5 m high a half-roof to reduce the noise effect and the other sides have been covered with wire fences. The side of the houses is the wall and the distance from the chiller to the nearest family houses is 12 m. However, the residential area up to 100 m away actually is impacted by the chiller noise. Air-cooled liquid chillers are located in the garden of an official institution in an area where there are many residences in the city center of Adıyaman. One of the two chillers is only operated alternately during the weekdays between the hours of 08.00-17.00. Chiller has caused environmental noise disturbances, especially on hot summer days. These houses have a history of complaints about chiller noise. Following the complaints, the Provincial Directorate of Environment and Urbanization requested that the noise of chillers should be reduced to the desired values in the regulation. Thereupon, official institution management desired to reduce mechanical noise in the immediate vicinity. The general structure of the air-cooled liquid chillers is shown in Figure 1.

Figure 1. Air-cooled liquid chillers

2.2. Applications to reduce the noise of the chiller

There are different noise attenuation options available to further reduce the noise level at its source thereby meeting environmental noise level regulations. In this study on these noise problems, chillers first enclosed by 18 cm brick walls for noise reduction. The dimensions of the chillers' noise isolation room built in the garden of the institution are 3.5x5x22 m (HxWxL). After that, the inner surfaces of the brick walls were covered with a 40 mm 50 dns fireproof acoustic pyramid sponge. Chillers' noise isolation room is shown in Figure 2.

Daytime sound level measurements were performed to characterize noise emissions and propagation for existing chiller and ambient conditions using a portable noise measurement device. The acoustic measurements were performed using a type 1 Cesva SC310 (Cesva instruments, SL, Barcelona, Spain) a sound-level meter and analyzer (integration time 1s, 125 ms and 35 ms LAS, LAF and LAI, respectively) which was calibrated by a sound calibrator Cesva CB006 (94 dB 1000 Hz). The octave-band frequencies ranging from 31.5 to 16,000 Hz and the one-third-octave-band frequencies ranging from 20 to 10,000 Hz was measured in all cases. The acoustical evaluations of environmental noise were performed, as described in ISO 1996-1 and ISO 1996-2 entitled ‘‘Description, Measurement and Assessment of Environmental Noise” [28, 30] and in ISO 9613-2 entitled "Attenuation of Sound during Propagation Outdoors" [15].

Figure 2. Isolation room for air-cooled liquid chiller noise

In accordance with the ÇGDY, the measurement point outside the nearest house that may be uncomfortable was 1 m in front of the façade. Measurement points for the noise maps have been determined such that the difference between the measurement points does not exceed 5 Leq dBA. The noise of the chiller was measured 1 m away from the chiller. The location of the chillers with respect to neighboring family houses is shown in Figure 3. Chiller is located in an area where houses are densely located between commercial buildings and noise-sensitive uses. The background noise of the area where the study was conducted was made between the chiller and the houses that suffered from chiller and in the garden of the institution where the chiller is located. At each point, the noise level was measured at a height of 1.5 m for at least 5 minutes. IDW (Inverse Distance Weighted) interpolation method in ArcGIS 10.1 software has been used for noise mapping and analysis. Accordingly, the Leq dBA noise maps in the immediate vicinity of the chiller have been generated for the background noise of the working area and before and after control the chiller noise.

Figure 3. Location of the chillers with respect to neighboring family houses.

3. RESULTS AND DISCUSSIONS

If the chillers are used in noise-sensitive outside locations, the noise level must be carefully evaluated. The chiller is generally located at ground level outside the building to ensure efficient airflow with fans and not to carry the weight of the cooling system into the building. This outside location implies that noise generated by the chiller should be surveyed cautiously in terms of nearby buildings. In this case, it is very necessary that there should exist acceptable environmental noise emission standards. According to the Turkey noise regulations, the noise level transmitted from the air conditioning system located outside the building to noise-sensitive areas cannot be exceeded the background noise level more than 5 dBA in terms of Leq noise indicator [25].

The noise of a chiller is a combination of several individual sources of noise. Therefore, the noise source cannot be considered as the point noise source. The distance between the source and the receiver must be more than twice the largest dimension of a source element so that a noise source can be identified as a point source [28, 31]. In this study, at the distance of 1 meter from the chiller, which is an imaginary parallelepiped measurement surface (Figure 4a) of total surface area (S m^2), is considered around the chiller. If the sound pressure level (SPL) or sound power levels (SWL) are provided, then the following equation is true:

$$SPL(at\ 1\ m) = SWL - 10 \times logS_{(1m)} \tag{1}$$

This equation can be used to calculate the noise levels at desired distances [32]. The fact that there is a near field and the presence of structures that will affect the sound waves around the chiller has the potential for error in the calculations. The original distance SPL calculation will variably produce a different value. This is due to the general complexity of predicting near-field noise levels, lack of directivity data and variations in the shape of the measurement plane. If sound pressure levels are provided with acceptances though, then the reduction from one distance to another (Re) can be determined by the following equation.

$$Re = 10 \times log\left(\frac{S_1}{S_2}\right) \tag{2}$$

where S_1 is the area of parallelepiped five-sided surface which is L_1 distance away from the chiller, and S_2 is the area of parallelepiped five-sided surface which is L_2 distance away from chiller [32]. Chiller operates at different loads until idling when it first starts and depending on the weather and the desired indoor temperature. In the study, it was determined that the chiller noise at a distance of 1 m from the midpoint of the long edge of the chiller at different operating loads was between 89 and 104 dBA. Noise in the sound source and the environmental factors affecting the noise in the working area are variable. For this reason, the change of chiller noise according to distance has been calculated up to the receiving point (Figure 4b). According to Figure 4b, the SPL level is reduced by approximately 11.8 dBA at a distance of 11 m from the sound source. SPL was measured as 90.6 Leq dBA at a distance of 1 meter from the chiller and 69.9 Leq dBA at a distance of 11 m from the chiller. In total, SPL decreased by 20.7 dBA at a distance of 11 m. In this case, it is understood that 90.6-11.8-69.9 = 8.9 Leq dBA SPL decreases due to the unilateral walls built in the direction of the chiller and other environmental structures. Figure 1 shows the ground-mounted, air-cooled liquid chillers. The closest residential property line from the chiller is approximately 12 m. However, the residential area up to 100 m away actually may be uncomfortable by the chiller noise. The streets between the chiller and residential area are generally active. Moreover, the noise level of the residential area is increased with the chiller. Five-story institution-building behind the chiller and asphalt and concrete floor around the chiller are reflective surfaces for the noise so that the chiller noise has been reflected toward the residential area. A few trees and garden walls as barriers exist between the chiller and surrounding residences. The residential area is part of Adıyaman, a densely populated during the day and relatively underdeveloped city district. Background sound level of the area is moderately in the summer months, except for the occasional workplace or non-home activities. In addition, the density of traffic in the street increases at the start and end of the work time due to especially the official institution where the chiller is located.

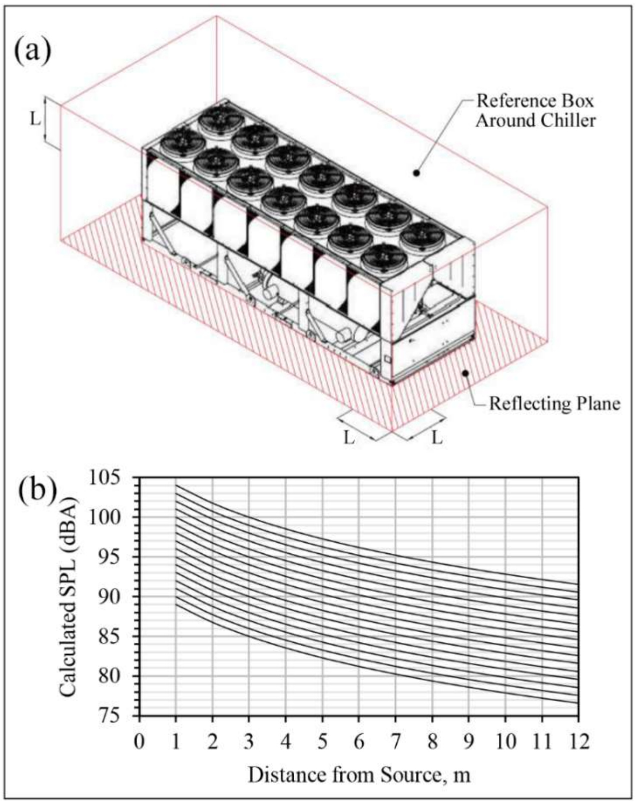

Figure 4. The parallelepiped of the imaginary five-sided constructed at a distance of L meter from the chiller faces (a), the change of chiller noise according to distance (b).

In the institution garden and the street, where the chiller is located, were measured LAS (t: 1s), Leq dBA (t: 5 s) and (t: 30 min) with a type 1 sonometer. As seen in Figure 5 (a) and (c), 30 minutes SPL values were measured as 55.7 and 61.8 Leq dBA, respectively. During the 30-minutes measurement of the background noise level, the LAS and Leq (t: 5 s) values ranged between 54-64 dBA and 54.2-61.6 dBA in the institution garden, 50.9-80.9 dBA and 51.1-78.5 in the street, respectively. A large number of noise indices have been proposed by many researchers to assess environmental noise. The A-weighted equivalent SPL shown by Leq dBA is the most commonly used of the recommended parameters. This parameter takes into account the magnitude of noise and sensitivity at different frequencies, is simple to measure and gives important information to the assessment of the noise annoyance [33-35].

A-weighted statistical noise levels (indicated by L1-99) are important because they take into account the time-dependence of noise. A-weighted statistical noise levels Ln are particularly used in community noise and road traffic assessments in order to try to better account for noise levels fluctuations in and the intermittent noise character. The level Ln defines the SPL which was exceeded for n% of the time [36]. Figure 5 (b) and (d) shows the statistical distribution of the noise levels in the institution garden and the street, respectively. For example, L5 is 66 dBA in Figure 5 (d), so the SPL is for 5% of the time for the period measured is higher than 66 dBA and the rest is less than 66 dBA. The L90 level is generally considered as an approximation of the background or residual level (also referred to as ambient level). L50 which is a useful measure of the audibility of noise from a planned facility is a mean sound level. The L10 which takes account of any annoying peaks in noise is most commonly used for road traffic noise assessment Furthermore, in many cases, L1 is used as a measure of the peak noise level [37]. In the study, L90 levels were determined as 54.8 and 51.9 dBA in the garden of the institution and on the street, respectively. The L50 noise levels were 55.5 and 56.5 dBA at the institution garden and street, respectively. While the noise level difference between L50 and Leq was 0.2 dBA in the garden of the institution, this difference was 5.3 dBA due to traffic noise in the street. Also, L10 and L5 define the noise peaks, and the difference L10–L90 defines the noise fluctuations or noise climate [38, 39]. The difference L10 – L90 and Leq represents as the sum of the noise pollution level, and defines the degree of annoyance that is caused by fluctuating noise [40]. As shown in Figures 5 (b) and (d), The L5, L10 and L10-L90 values were found as 57.5, 56.6, 1.8 dBA and 66, 63.6, 11.7 dBA at the institution garden and street, respectively. In particular, according to L10-L90 data, there is a traffic fluctuation in the street. The sound caused by traffic is often a noise disturbed roadside residents [41]. The traffic noise index (TNI) method used to estimate the annoyance response caused by traffic noise was calculated according to the following equation [42].

$$TNI = 4 \times (L10 - L90) + L90 - 30 \text{ (dBA)} \qquad (3)$$

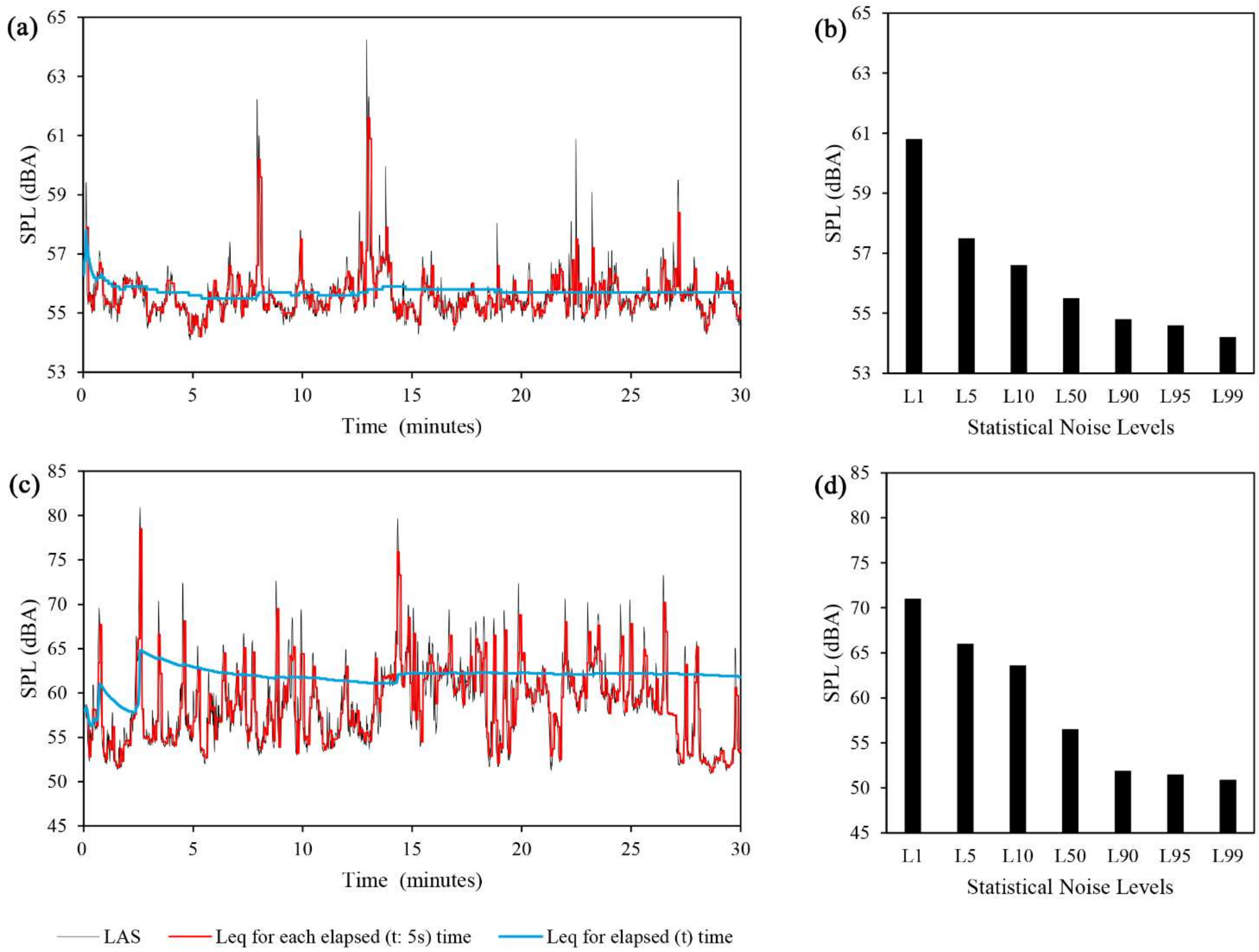

Figure 5. In the institution garden (a, b) and the street (c, d), where the chiller is located, sound level measurements and their statistical analysis.

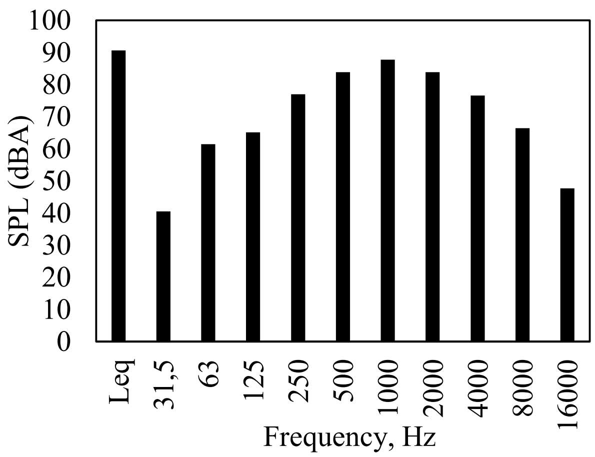

Figure 6. The chiller A-weighted octave band spectra and sound level (Leq) noise measurement with a sonometer location 1m away from the chiller

According to Figure 5 (b) and (d), the TNI in the present study were 32 and 68.7 dBA, respectively. Also, the noise pollution level (LNP), which describes the traffic noise taking into account the temporal fluctuations of noise levels, is calculated according to the following equation [43].

$$LNP = Leq + (L10 - L90)\ (dBA) \qquad (4)$$

According to Figure 5 (b) and (d), the LNP in the present study were 57.5 and 73.5 dBA, respectively.

The chiller cooling system was operated in order to assess the strength of the noise emitted from the system and the SPL emitted from the system was octave and third-octave band analyzed. Figure 6 shows the chiller A-weighted octave band spectra and sound level (Leq dBA) obtained at a central point located 1 m away from the chiller. Since the chiller fan and coolant pump cannot be operated separately, the noise emitted from these systems was calculated as a whole. The peaks of the SPL for the chiller A-weighted octave band are ascended 63 and 2000 Hz, whereas in the third-octave band are ascended 63, 125, 250, 8000, 2000 and 6300 Hz. The peak for the octave and third-octave band A-weighted SPL is at 1000 Hz (87.8 dBA) and 800 Hz (85.4 dBA), respectively. The sound pressure octave band spectra of the chiller showed that high noise mainly in the frequency range 250 to 4000 Hz was present at between from 76.7 to 87.8 dBA. In fact, there is no significant contribution to the increase in the total sound level of values smaller than 10 dB from the peak sound value in the spectrum of the octave band.

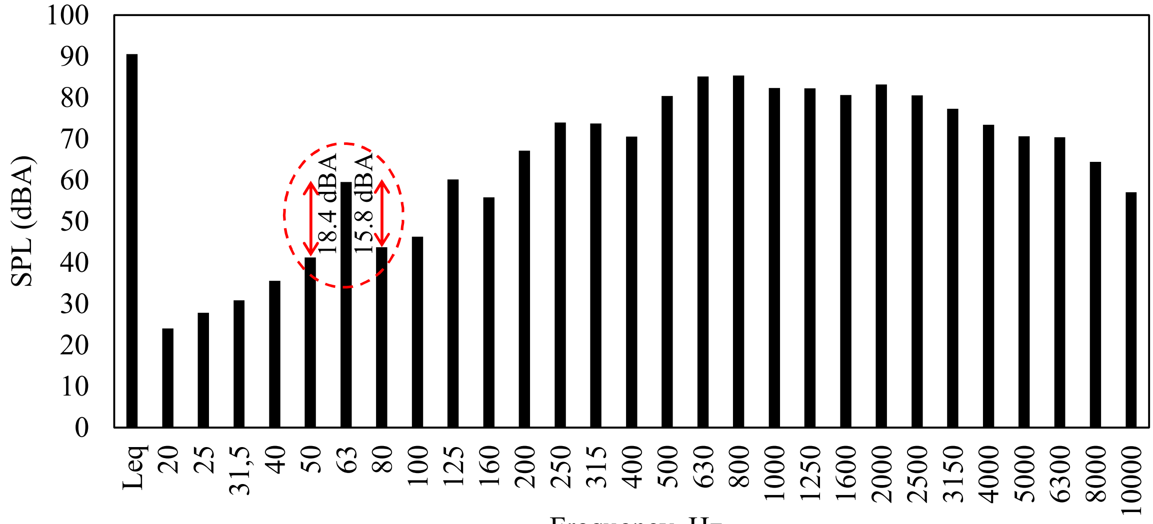

Figure 7. The chiller A-weighted one-third octave band spectra and sound level (Leq) noise measurement with a sonometer location 1 m away from the chiller

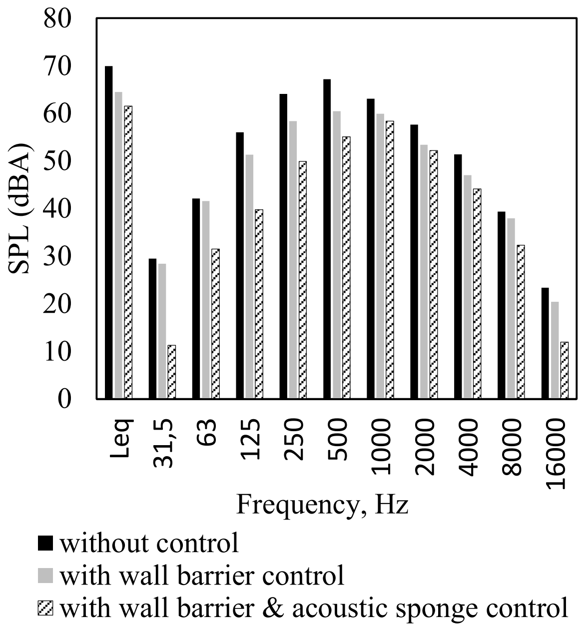

Figure 8. A-weighted octave band spectra and sound level (Leq) measurements 1 m away from the building nearest the chiller (11 m away from the chiller)

One-third octave band, the 63 Hz band value exceeds 50 Hz band value by 18.4 dBA and the 80 Hz band value by 15.8 dBA (Figure 7). That is, the 63 Hz band is a pure tone noise because the SPL on both sides exceeds 15 dBA. On the other hand, in the 1/1 octave band, pure tone noise cannot be seen. As shown in Figure 8, passive noise reduction measures further reduced the noise level octave bands. However, the noise level in the 63 Hz band appears to be slightly more resistant than the other bands. Accordingly, noise reduction studies have mostly eliminated pure tone noises that may occur.

The noise level measured in terms of the Leq noise indicator 1 m away from the nearest structure was 69.9 dBA, whereas the noise level reduced to 64.5 dBA after brick wall application and reduced to 61.5 dBA after the brick wall was covered with the acoustic sponge. Avşar and Gönüllü [41] obtained that the importance of a noise reduction barrier for sensitive areas. The combination of wall barrier treatment and the acoustic sponge resulted in approximately 8.4 Leq dBA noise reduction at 1 m away from the building nearest the chiller (11 m away from the chiller). The noise level at 11 m from the chiller is reduced 5.4 Leq dBA by the brick wall while reducing 3 Leq dBA by acoustic sponge. In the uncontrolled case, the bands between 125 and 2000 Hz are predominant sounds, but the bands forming the main noise are 500 Hz (67.2 dBA) and the bands next to it. The peak band is 500 Hz (60.5 dBA) again after the brick wall barrier control, but it has reached the approximately same level with the near bands (58.3 dBA for 250 Hz and 59.9 dBA for 1000 Hz). After the acoustic sponge application on the wall barrier, the peak sound level was determined to be in the 1000 Hz band (58.4 dBA). Furthermore, the 1000 Hz band is more resistant to noise abatement than other bands.

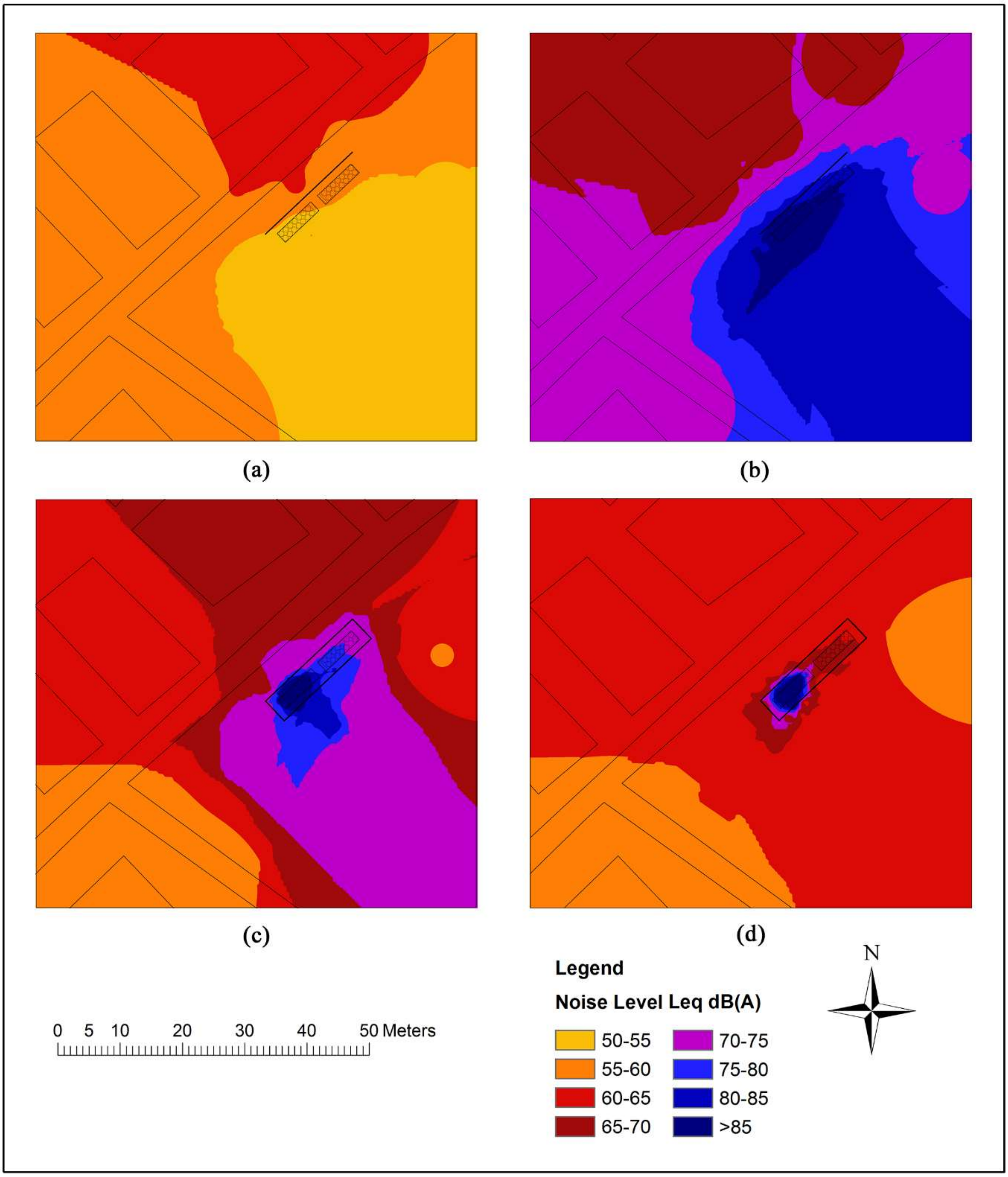

Figure 9. The noise maps in the immediate vicinity of the chiller; the background noise (a), chiller noise for the uncontrolled condition (b), chiller noise after the wall barrier is constructed (c), chiller noise after the application of the wall barrier and acoustic sponge (d)

Figure 9 shows background noise map, chiller noise maps for the uncontrolled condition after the wall barrier is constructed and after the application of the wall barrier and acoustic sponge in the immediate vicinity of the chiller. Figure 9 (a) shows that the background noise levels are between 50 and 65 Leq dBA. Figure 9 (b) shows that the noise of the chiller in the uncontrolled state is above 65 Leq dBA in the vicinity of the chiller. It is also seen that the noise levels reaching the street and nearby houses are in the range of 70-75 Leq dBA. The street-side wall reflects the noise of the chiller towards in the garden of the institution. For this reason, the noise level the garden of the institution is 75 Leq dBA and above in the uncontrolled state. As seen in Figure 9 (c), when the chiller is closed with brick walls, the noise outside the institution garden is at the level of 55-70 Leq dBA while the noise inside the institution garden is above 70 Leq dBA. It is also seen that the noise coming from the air entrance openings opened to the wall floor of the chiller room has reached more towards the garden of the institution. Figure 9 (d) shows that, except for the close distance of 5m of the chiller chamber, the environmental noise values from the chiller are reduced to between 55 to 65 Leq dBA that is background noise level. In addition, the noise from the chiller to ambient has dropped to background noise levels (55-65 Leq dBA).

In the design process, the chiller should evaluate the noise problems of the equipment. For noise reduction studies, only sound power, sound pressure levels and 1/1 - 1/3 octave band data can be obtained from the manufacturers. It is also very difficult to obtain these data for each model chiller. Therefore, if the selected equipment is to be located in a location that can generate environmental noise, the installation, and operating documentation must contain 1/3 octave band data. With this data, a distance-related decrease of the sound level of the chiller can be estimated to determine the distance and operating conditions that the near neighbors will not be affected by the noise of the chiller. According to these calculations, it is possible to decide the sound limit setpoint program in the latitude chiller [44]. Figure 10 shows that ordinary air-cooled screw chillers and latitude chillers exhibit a relative reduction in sound level when operating at off-design conditions, which occur whenever the outdoor temperature is below its design maximum. This feature of the chiller is claimed to eliminate the need for additional noise reduction, such as sound barrier walls. In Figure 10 it is seen that if the ordinary air-cooled screw and latitude chillers are operated at the lowest load, the SPL will be decreased up to 3 and 9 dBA respectively. [45]. However, on hot summer days, if the chiller is operating at full load, additional noise reduction measures become a necessity not a choice. Therefore, alternative equipment types, appropriate equipment locations, and required noise measures should be considered at the very beginning of the installation process.

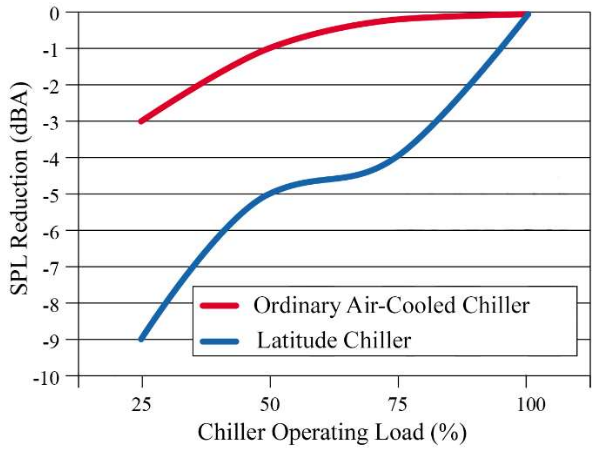

Figure 10. The SPL reduction values (dBA) when operating at off-design conditions of ordinary air-cooled screw and latitude chillers that operated for different loads.

In this study, the noise level of the surrounding residences was reduced to the background level in the general working condition of the chiller. However, chiller operation at high loads may change this situation. In addition, since the top of the chiller is not covered, it prevents full control of the noise. This means a higher risk of noise for the upper floors of buildings in the immediate vicinity. Therefore, it is recommended to consider a special noise-reducing mechanism that can cover the top of the chiller in subsequent studies. In addition, it has been observed that the closure of the chiller surrounds makes the air movement with cooling fans more stable from bottom to top. In other words, the airflow around the heated chiller equipment has become more mobile. This is thought to contribute positively to the cooling process of chiller fans. In addition, it is thought that the service life of the system is prolonged because it is protected from cold-hot and sunlight interactions by covering the chiller system. However, if the chiller is covered more than necessary, the temperature of the system will increase in a short time and the system will automatically shut itself down. This will disrupt the cooling function, which is the main purpose of the chiller.

4. CONCLUSIONS

The institution chose in order to implement the two recommendations, to enclose the chillers with brick wall, and cover the inner surfaces of the brick walls with 40 mm 50 dns fireproof acoustic pyramid sponge. The combination of brick wall barrier and acoustic sponge achieved a noise reduction of approximately 8.5 Leq dBA 11 m away from the chiller (1 meter away from the nearest building to the chiller). The brick wall reduced the noise 11 m away from the chiller by approximately 5.5 Leq dBA, while acoustic sponge on brick wall as plus was reduced by approximately 3 Leq dBA.

As a result of this study, complaints in the vicinity have been significantly reduced, but not eliminated. That the complaints are not eliminated likely is owing to the chiller produces uninterrupted noise despite reducing of the noise level. This uninterrupted noise makes the presence of chiller noise more prominent. Additional noise reduction should also be achieved with a suitable structure constructed on the chiller acoustic barrier or acoustic barrier should be extended a few meters higher than the chiller.

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Research and Publication Ethics

In all processes of this paper, it was acted in accordance with the research and publication ethics principles of Sakarya University Journal of Science.

Ethics Committee Approval

Ethics committee permission is not required for the data in this paper.

Conflict of Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this paper.

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