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REVIEW ARTICLE

# Analysis of different methods of suppressing generator noise reaching indoor noise

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**Abstract**: The noise which occurs during the operation of the auxiliary power units is a disturbing factor, although its level varies depending on the environment. This high level of noise in occupational areas can cause not only health but also accidents risks. While silencers are mostly preferred for active noise control, acoustic foam or textile products are preferred according to passive control methods. In this review, the noises produced by the generatorswere examined and the studies in the literature on suppressing these noises were evaluated by making comparative analyzes. New recommendations have been developed according to the results of the comparative analysis. In case the sampled natural gas generator is closed with 2 mm thick plywood and a steel framed box covered with an acoustic sponge, the sound pressure level is approximately 30 dB in low frequency diesel + electric generators using a silencer according to active control methods. In measurements; It was observed that it decreased from 93.2 to 88.4 dB. While materials such as an acoustic sponge, which are preferred in passive control methods, are open-celled and porous structures, it is advantageous to have sound absorption capacity, but it can be a disadvantage due to its synthetic content.

**Keywords**: Sound, Noise, Acoustic, Generator Noise, Active Control Methods.

## 1. Introduction

While technological developments offer important opportunities, they can also bring many negativities. One of the undesirable conditions is the disturbance effect caused by vibration and noise. The noise continues to be one of the important problems of today, as it is disturbing and can threaten human health if exposed for a long time. To protect cities and residential areas from noise, measures to be taken against noise in industrial areas and sensitive areas of the city are increasing and new studies are being carried out in this regard. To protect cities and residential areas against noise, which is included in the "Regulation on the protection of buildings against noise" of the Official Gazette published in 2018, measures to be taken against noise in industrial areas and sensitiveareasof the city are increasing and standardsare being brought in this regard [1].

"Regulation on the Protection of Buildings Against Noise" was published in the Official Gazette No. 30082 on May 31, 2017, and entered into force on May 31, 2018 [2]. In order to better understand these studies and noise, its relationship with sound should be examined.

Sound, which occurs as a result of the compression and relaxation of molecules through a medium such as solid, liquid and gas, as a result of the effect of vibrations emitted from an energy source and is perceived by a receiving mechanism such as the human ear or microphone, can be expressed as noise even though these vibrations are disturbing [3,4,5]. Accordingly, noise is also accepted as an acoustic phenomenon perceived by a person or group, defined as unpleasant or disturbing. When exposed to noise, physiological or psychological responses occur [6]. If the unwanted sound is louder, an increase in these responses can be observed. Although sound is known as an objective concept that can be measured and whose existence does not change from person to person, factors such as the intensity of the noise, its frequency, the amount of background noise, hearing loss and psychological effects vary from person to person [4,7]. occurring in the industrial area for production purposes, which remains constant in a certain time interval, and instantaneous noises with a high level occurring in less than one second [7]. Additionally; in different environments, noise from construction, music from entertainment, noise from traffic and airplane noise, etc. noise has been reported [8].

The sound pressure level and exposure times of these noises are important. These standards are determined by the ILO (International Labor Organization) in terms of work, and it is preferred that the sound pressure levels cre-

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ated by the sound are not above certain limits according to the determined working times. In ILO standards, the operating time at 90 dB is determined as 8 hours [9].

At the same time, NVH (Noise Vibration and Harshness) is determined by noise legislation and increasing customer demands. In this sense, acoustic behavior should also be known [10]. Gerges et al. According to (2001), noise, which can be a common occupational hazard in many workplaces, is common in the iron and steel industry, foundries, sawmills, textile mills, airports, and aircraft maintenance shops, crushing mills, etc. As noise-induced hearing loss in environments is known as the most common occupational disease [11], exposure to high noise levels can cause permanent damage to hearing [12]. In the study of Valley (2001), it was stated that noise is a factor that negatively affects the quality of life of people, since it has significant environmental effects, although it is temporary [13]. The aforementioned negativities enabled the development of solution proposals. For this reason, studies on occupational sound levels have been made in some sources, and reference values are listed for each source [14].

For example, noises originating from mechanical parts such as wind turbines, which can be described as mechanical noises, can be listed as auxiliary equipment such as gearbox, generators, drift drivers, cooling fans, hydraulics [15].

Some devices, tools, or machines, which are described as auxiliary equipment, are disturbing factors that can be encountered as noise sources. It is inevitable to take necessary measures to minimize such noises [16]. To determine the harmful effects of sound pressure on people and to be more controlled, evaluations can be made by arranging noise maps [17]. Caliskan et al. (2011) stated in their study that these maps, in addition to being regional or local, are preferred to be prepared at certain times of the day [18]. It is stated that a noise map should be made for the stage, tent, generators and other structures that are planned to be used temporarily on the facility or an area [19]. In this study, noise map for generators can be drawn since the issue of noise in generators is examined. Thus, areas that are significantly affected by environmental noise can be distinguished and appropriate measures can be taken in these areas [20]. Today, the necessity of using commercial and industrial generators, commercial workplaces and industrial production areas leads to the need to evaluatethe noise generated by these generators [21]. The source of the sound, the path of the sound and the receiver, which are known as the parameters for feeling the presence of the sound, should be evaluated separately. In this sense, one of the most important factors in taking the noise under control is to reduce the noise at its source. Therefore, the environment can be protected fro m the noise generated at the source. Another important point is that the noise can be reduced in the area where it spreads. However, it is known that reduction at the source is more effective [22]. E.g; in the evening i.e. in quieter situations, loud radios, generators etc. It is important to minimize the disturbance problem [23]. In our study, reducing the noise in generator types with different materials with acoustic properties will provide an innovation in this regard. Generator types; Examples of portable (portable or emergency) models that work with natural gas and/or propane, which cause constant noise, are permanently installed, are fixed, work with diesel or gas, which cause intermittent noise, and are preferred in residential or commercial areas [24]. Noise levels will be within the specified range. The weatherproof and sound attenuated enclosure construction will limit the noise level to 70 dBA at 7 meters or 80 dBA at 1 m at full continuous load [25]. These measurements can be logarithmic or arithmetic. In a study in which the differenceis expressed depending on the measurement of these two concepts, when a measurement is taken at a distance of 7 meters from all four sides of a generator, right, left, front and rear; 93 dB measured logarithmically and 90.5 dB measured arithmetically. It has been determined that the logarithmic measurement of the sound pressure level gives healthier results. In addition, it was stated that the sound pressure level of a generator should be measured from four different directions as mentioned [26].

In measuring the common generator noise level, the dB(A) value, which is the A-weighted sound pressure level, is measuredat a distance of 7 meters in free space. The free areashould not be on surfaces that reflect the sounds of the generator, such as walls and buildings, close to the measurement area [27]. In another study on the importance of distance and noise; It is stated that a generator at a distance of 15.24 meters produces 107 dB (A) of noise. It is also important to regularly test and maintain backup generators [28]. The measurement of air emitted noise is included in the International Standard ISO 8528 -10 [29]. This measurement standard is taken into account in the studies that can be done about the measures taken to reduce noise in generators. In line with the standards, sound insulation procedures are carried out to allow the operation of tools and devices that should be used in road and construction works, paying attention to the time period that is sensitive to noise, to eliminate noise disturbance and to prevent health problems, especially in settlements [30].

At the same time, applications such as insulation works to reduce generator noise, placing sound-absorbing barriers on suction louvers and using fan silencers are the methods used to reduce generator noise [31].

The contributions of this study to the literature on the analysis and evaluation of the noise level arising during the operation of generator types according to their nature and environment are sum marized as follows:

- i. Studies in the literature for acoustic masking methods, which have important contributions in minimizing the noise produced by generators, were examined in detail and the results were compared.

- ii. When the active noise level reduction methods in the application were examined, it was seen that the most efficient results were obtained by using a silencer.
- iii. When the passivenoiselevel reduction methodsin practiceare examined, it has been seen that different quality products obtained from the acoustic sponge with porous, in other words, open -cell structures, or textile materials with sound-absorbing features provideadvantages. In this sense, the acoustic contributions of each product are presented.
- iv. The importance of the distance parameter in increasing the efficiency of alternative solutions determined for reducing noise in generators is also mentioned. This situation has brought positivity to the studies carried out.
- v. Although many materials with sound absorption features are advantageous among the materials used, it can also be seen that they cause disadvantages due to the synthetic raw materials in their content. To overcome these disadvantages, suggestions have been made to produce products with natural materials that can be preferred as an alternative, recyclable, less harmful to human health and environmentally friendly.

In addition, these natural materials will be able to provide significant gains in reducing carbon emissions, which is one of the important issues today. In this study, to compare the methods used in reducing the generator noise, in the second part, the definition of the generatorand thesound pressurelevelsof thenoises it produces are given and acoustic solutions (passive and active methods) are mentioned. In the third part, the results obtained according to the literature review are given. In the fourth chapter, the sound pressure levels of the generators according to their types and the acoustic solutions developed to reduce these pressure levels are comparatively examined. In the last part, new solutions to be investigated to reduce generator noise are presented.

## 2. Material and Method

Generators are known as machines that can convert mechanical energy into electrical energy and work with the principle of electromagnetic induction (Faraday's Law) [32]. Vibration and noise during operation occur when the sound is above a certain level. Humans can hear sounds in the frequency range of 20-20000 Hz under normal conditions. [33]. In this case, the sound pressure level, which may differ according to the frequency ranges, is the response of people and objects to the sound in the air and is often known as a concept that needs to be controlled, but depends on the sound source and measurement location. Sounds above 700 Hz begin to damage the ear [34]. In terms of these analyses, the analytics of the sound source can also be important. If we evaluate generators in this sense, it is understood that they produce different noise according to their size, capacity and design. Since these sounds at different frequencies and pressure levels directly affect the subjective concept of "noiselevel", they should be regulated by laws, not standards [27]. A sound level meteris used to measurethe noise level [35]. The value obtained from this measurement is also expressed in dB (A) [36].

Our study aims to compile studies on noise in generators and to minimize the negative effects of noise on people. Therefore, it is also important to be protected from the harmful effects of noise, to create healthy and comfortable living spaces and to prevent occupational accidents in the workplace [37].

For this reason, insulation processes are also increasing in industrial areas and since using today's preferred technologies makes sound absorbing and sound-reducing insulation materials increasingly important [38], parameters such as which generators are more effective and how much sound insulation can be provided are analyzed.

Accordingly, in this study; first of all, the general structures of the generators and the elements in them are introduced. Then, the noises produced by the generators were examined and the studies in the literature for the acoustic masking method were given in detail. At the end, the results of these methods are compared and suggestions for new studies to be done are given.

### 2.1. Generator

Preferred methods are applied within the framework of these standards (Military facilities, etc.) in critical places in the form of power centers where network infrastructure costs are very high [39]. In addition, it must be of a quality to providereliability, availability, voltage and frequency characteristics as well as being known as secondary electrical power [40]. Although it is classified according to fuel types (diesel, gasoline/LPG, natural gas, etc.) and working methods, it is widely used in factories, motorboats and trains [41, 42]. Generators also differ in size, shape and feature. Dimensional values of a diesel generator are given in Table 1 [43].

Dimensional values etc. of a diesel engine generator in Table 1 is seen. According to these data, the dimensions vary according to the generator types [43]. At the same time, the concept of power is among the issues that need to be analyzed. Because generators are mechanical devices, criteria such as maintenance and control are among the elements that should be evaluated in terms of efficient operation. In power systems, control is usually applied to

**Table 1.** Dimensional Values of Diesel Generator [43]

| Generator Set, 50 Hz, 400 V | | | Dimensions (meter, m) | | | Room Size (metre, m) | | | Radiator Hot Air Outlet Window (meter, m) | | | Air Inlet Window Total Area (meter, m) | Room Door Size (meter, m) | | Exhaust | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Engine Model | Model | Standby Power (kVA) | Lenght | Width | Height | A Lenght | B Width | C Height | D | E | K* | | L | M | Dia-meter (inch) | P (meter, m) |
| S3.8-G6 | AC 55 | 55 | 1.78 | 0.95 | 1.28 | 3 | 3 | 2.5 | 0.7 | 0.65 | 0.6 | 0.46 | 1.5 | 2 | 3 | 2 |
| S3.8-G7 | AC 66 | 66 | 2.15 | 1.05 | 1.52 | 3.5 | 3 | 2.5 | 0.7 | 0.7 | 0.7 | 0.5 | 1.5 | 2 | 3 | 2 |
| 6BTA5.9-G5 | AC 110 | 110 | 2.2 | 1.05 | 1.63 | 4 | 3 | 2.5 | 1 | 1.1 | 0.5 | 1.1 | 1.5 | 2.2 | 3 | 2 |
| 6BTAA5.9-G6 | AC 150 | 150 | 2.75 | 1.3 | 1.82 | 4.5 | 3.5 | 2.5 | 0.95 | 1.25 | 0.6 | 1.2 | 1.8 | 2.4 | 3 | 2.2 |
| 6BTAA5.9-G7 | AC 170 | 170 | 2.75 | 1.3 | 1.82 | 4.5 | 3.5 | 2.5 | 0.95 | 1.25 | 0.6 | 1.2 | 1.8 | 2.4 | 3 | 2.2 |
| QSL9-G5 | AC 350 | 350 | 2.9 | 1.3 | 1.94 | 5 | 3.5 | 3 | 1.2 | 1.3 | 0.5 | 1.6 | 1.8 | 2.5 | 4 | 2.5 |
| NTA 855-G4 | AC 400 | 400 | 2.96 | 1.55 | 2.14 | 5 | 3.5 | 3.3 | 1.25 | 1.5 | 0.55 | 1.9 | 2 | 2.6 | 6 | 2.5 |
| QSX15-G6 | AC 500 | 500 | 3.38 | 1.55 | 2.1 | 5.5 | 3.5 | 3.3 | 1.7 | 1.6 | 0.45 | 2.8 | 2 | 2.6 | 8 | 2.5 |
| QSX15-8G8 | AC 550 | 550 | 3.38 | 1.55 | 2.1 | 5.5 | 3.5 | 3.3 | 1.7 | 1.6 | 0.45 | 2.8 | 2 | 2.6 | 8 | 2.5 |
| VTA28-G5 | AC 700 | 700 | 3.81 | 1.55 | 2.27 | 6 | 3.5 | 3.5 | 1.5 | 1.5 | 0.65 | 2.25 | 2 | 2.6 | 2*6 | 2.6 |
| VTA28-G6 | AC 825 | 825 | 3.81 | 1.55 | 2.27 | 6 | 3.5 | 3.5 | 1.5 | 1.5 | 0.65 | 2.25 | 2 | 2.6 | 2*6 | 2.6 |
| QSK23-G3 | AC 880 | 880 | 4 | 1.71 | 2.26 | 6.5 | 4 | 3.5 | 1.9 | 2 | 0.25 | 3.8 | 2.4 | 2.7 | 8 | 2.7 |
| QST30-G4 | AC 1100 | 1100 | 4.4 | 1.78 | 2.35 | 7 | 4.5 | 4 | 2.1 | 2 | 0.3 | 4.2 | 2.5 | 3 | 2*6 | 3.1 |
| KTA38G5 | AC 1100K | 1100 | 4.4 | 1.78 | 2.37 | 7 | 4.5 | 4 | 2.1 | 2 | 0.3 | 4.2 | 2.5 | 3 | 2*6 | 3.1 |
| KTA50-G3 | AC 1410 | 1410 | 4.94 | 2.1 | 2.4 | 8 | 4.5 | 4 | 2.3 | 2.1 | 0.25 | 4.8 | 2.7 | 3 | 2*6 | 3.1 |
| KTA50-G8 (GS8) | AC 1675 | 1675 | 5.45 | 1.95 | 2.45 | 8 | 4.5 | 4 | 2.25 | 2.25 | 0.2 | 5 | 2.7 | 3.5 | 2*8 | 3.6 |
| QSK60-G4 | AC 2250 | 2250 | 5.9 | 2.3 | 3 | 9 | 5 | 5 | 2.8 | 2.7 | 0.2 | 7.5 | 3.1 | 4 | 2*10 | 4 |

frequency, voltage, and other electrical parameters [44]. The power of the generator is also reflected in the sound during operation. This may be different depending on the type of fuel. Diesel engines have been found to have higher operating pressures and higher noise problems compared to gasoline engines [45]. At the same time, it is possible to talk about the advantages and disadvantages of generators relative to each other. While these provide advantages because gasoline generators can be supplied in a short time, they have a short usage period, and generators with natural gas are easier to find, as well as being low in cost and difficult to transport, etc. can be exemplified as [46].

## 2.2. Noises Produced by the Generator

During the operation of generators, different noises occur depending on the source. It is important to determine critical levels according to noise sources. For these critical levels, it is recommended by the World Health Organization (WHO) that it should not be above 70 dBA. View of a generator and sound pressure levels according to the noise sources in the generator is given in Fig. 1 [47].

In Fig. 1, it was seen that the measurements were usually made at a distance of 3 feet/1 meter. The area surrounding a machine has been defined as the “near field”. In terms of designing the right solutions, the measurements were made at a distance of 3 feet / 1 meter and a height of 5 feet / 1.5 meters (typical ear height range). It is possible to reduce these levels at the source. For example, the value of 120 -130 dB(A) before the silencer is used in the engine exhaust can be reduced by only 15 dB by using the silencer. The residence time at a sound level above 90 dB should not exceed 8 hours [9]. In older generators, the sound pressure level is higher [48]. On this subject, in the study of Lee (2007), generators with a power of 5250 Watt (W) that worked less than 10 hourson average in 1 year and generators of 2250 Watts (W) that worked more than 100 hours in more than 10 years were compared. It has been determined that the older one in W power gives more sound due to vibration. In the measurements, accelerometers were placed in the horizontal and vertical directions and the study was carried out. In both generator types, the vibration peaked around 60 Hz. It has been observed that the 5250 W generator haspeaked at 60 Hz (vibration during the opening and closing of the generatordue to the rotational speed of the motor), while it has peaks varying up to 100 Hz in the 2250W generator, while it is in the frequency range lower than 20 Hz. While the acceleration in the horizontal axis was greater than that measured in the vertical axis, it was observed that peaks occurred at a frequency of 100 Hz in the 2250 W generator, reaching the highest level at 60 Hz. The 2250W generator acceleration and displacement is more than three times its magnitude [49]. This situation arises due to mechanical systems. In this sense, it is known that in generators with diesel engines, noise occurs with the effect of vibrations caused by the crank connecting rod mechanism, mass and

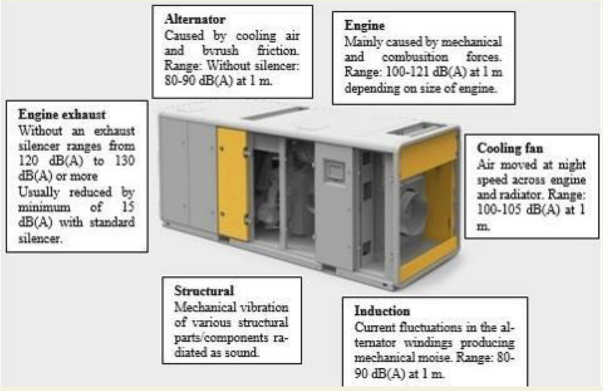


**Figure 1.** The appearance of the generator and the sound pressure levels according to the noise sources in the generator [47]

gas movements [50]. The fact that the vibration-induced noises are at the levels determined in the standards has become a situation that is expected to show parallelism in terms of the ergonomics of the working environment. Accordingly, motivation and health parameters are among the qualities to be considered. For example, the maximum allowable noise level in diesel generators was 75 dB(A) at 1 m from the closed surface in 2005 [51], in a later study it was found to be in the range of 100-110 dB without sound insulation [52]. In the study, it was determined to be 80 dB(A) at 1 mt distance [53]. It has been stated that the engine room in a small ship is the loudest place in terms of the sound generated in the room where the generator is located and varies between 90-115 dB(A) and this level is usually caused by the high speed and the propeller during maneuvering [54]. The expected sound pressure level may differ depending on the type. In the standby generator, it is suggested that the sound pressure level by 56 dB LAeq, 1 hour [55]. There are also studies on generators used in different environments. In a study conducted for Nigeria, the sound pressure level in generators used in buildings was 87.4 dB [56], in another study conducted in houses/offices in Southern Nigeria, sound pressure levels were 70, 75 and 90 dB [57], again in the same country.

In the research on generators, the noiselevel was obtained as 91.2 -100.5 dB(A). It has been determined that these levels can be dangerous for human health because they are above the permissible limits [58].

Active and passive methods, etc., to be at the forefront of health risks, to minimize generator noise, etc. led to the development of alternative solutions. In the preference of these alternatives, OSHA (Occupational Safety and Health Administration), etc. The standards detemined by the organizations are taken into account [59]. Preferred methods are applied within the framework of these standards.

## 2.3. Acoustic Solutions

The vibration occurs during the operation of generator engines. Therefore, it is recommended to wear ear-plugs to prevent hearing loss. In addition, since carbon monoxide (CO) gas, known as a toxic gas, is colorless and odorless and has dangers that may cause the death of many people, generators should not be used indoors and ventilation should be provided in the environments where the generator is located [60]. In this regard, the fan can be described as an important device. Air transfer fans are preferred because heating occurs during the operation of engines and generators [61]. Silencer [62] etc. in pipes and ducts to reduce airborne noises. Sustainability is ensured through Life Cycle Evaluation Procedures of natural materials that can be an alternative to many synthetic materials [63].

The existence of materials with many properties in nature is an advantage. By taking advantage of the acoustic properties of these natural materials, the sound energy is reduced by transferring the acoustic pressure to the material movement [47]. In studies on this subject, it has been stated that acoustic insulation materials with up to 51 mm (2 inches) or different thicknesses and properties are used to reduce the sound pressure level [64]. In addition to the use of natural materials with acoustic properties, different studies are also carried out on the mechanical parts of the generator that cause vibration and noise. Active/passive noise and vibration control technologies are used in the design of generator engines [65]. Since the noise levels differ according to the environment where the generators are located, the studies on this subject also vary.

## 2.4. Passive Methods

Different passive methods are applied depending on the shape, size, and functional properties of generators. Parvathi and Navaneetha (2003) conducted an experimental study to prevent vibration-induced noise in portable generators with a sandwich made of rubber, fiber, polyurethane foam, wool felt, sand, cardboard, and two materials, which is one of these methods. they have reduced the pressure level by 10 dB(A) [66].

In another study, the sound pressure level in the generator was 76.3 -91.5 dB (reduction amount 15.2 dB) without taking any precautions, and these values were obtained as maximum 60.4-77.9 dB (17.5 dB decrease amount) in case of closing with a textile product [67]. Demirel et al. (2018), in the study they carried out in the generator room of an international airport, materials such as rock wool, polymer, rubber and plaster etc. It has been suggested that noise can be effectively reduced by layers that can be formed with materials [68].

In another study, where the vibration of the generator engine is reduced and quieter operation is ensured, the importance of reducing the sound pressure level without increasing the cost is mentioned. Not just the 10 dB reduction cost but 500 Hz. The cost of reducing the noise above and below also varies. Because in general, single materials 500 Hz. sound absorption capacity is very low. Material properties are important in this regard. Therefore, it is important to reduce the sound pressure level without increasing the cost. To achieve this efficiently, some strategies are implemented. Noise reduction strategies vary depending on whether the generator is indoors or outdoors. Low-frequency noises are difficult to reduce, and high-frequency noises with rigid barriers are tried to be controlled with materials such as acoustic foam. In generators with a power up to 2,000 kW, sheet metal, etc. They apply sound reduction process by preserving them with materials such as However, special sound-insulated enclosures are used in generators with a power of more than 2,000 kW. Accordingly, in noise reduction strategies; acoustic barriers (usually steel sheet on the outer surface, a blocky sandy surface or cast wall is used on the inner walls), acoustic insulation material (acoustic foam is known to be effective in high-frequency noises), vibration isolation (with proper design of flexible fuel lines and evenings on the exhaust), vibration can be reduced), exhaust mufflers, etc. materials can be used [69].

In another study, acoustic materials are preferred because the barriers used in sections such as air inlet, exhaust and heat output in most power generators can pass noise. To obtain the sound pressure level, which is measured as 73.5 dB(A) on average in this type of generator, below 68 dB(A), the sound pressure level is obtained as 67.0 dB(A) by using an acoustic barrier applied to the polyester surface of the acoustic foam with aluminized. has been done. It has been stated that although the noises originating from the engine and exhaust have a low frequency in the range of 250 -315 Hz according to the noise source, there are high-frequency noises in the range of 1250-2000 Hz in the airflow, fan and alternator [70]. In terms of acoustics, glass wool is one of the most preferred products. Accordingly, Schnitta (2010), in his study o n the production of an acoustic barrier made of 2" (2 inches= 5.08 m) thick glass wool to prevent noise in generators, measured 72.3 dB at 0.9144 meters and approximately 60 dB at 3.66 meters. doubling the distance according to the inverse square rule in a "quiet" AC capacitor, approximately 6 dB at this value, at a maximum distance of 0.9144 m from a 1.524 m tall condenser, the noise level at the barrier window is approximately 6.6 dB at 125 Hz, at a height of 10 m. found that the noise level is reduced by approximately 14.1 dB at 125 Hz when the barrier is used [71].

It is possible to reduce the noise at the desired level by producing the materials with acoustic properties mentioned above in different thicknesses. In this sense, the acoustic material in the sponge structure used effectively is given in Fig. 2. This material can be produced in different thicknesses such as 1 cm, 2.5 cm, and 5 cm [72].

The noise can be reduced by 48-85 dB(A) at a distance of 1 m when high-density stone wall-filled perforated sheet metal is used as acoustic material [73].

203.2-micron thick neoprene coated, fiberglass reinforced, aluminized polyester white or foil film (1.5 mil/38.1 micron) coating and 48 kg/m$^3$ density glass fiber in 25 mm and 50 mm thicknesses, with 25 mm thick material and Noise Reduction Coefficient (NRC) as 0.75, with 50 mm thick material, the NRC was obtained as 0.94 [74]. The NRC curves here are a report for noise criteria and are characterized by a degree of interference measured by SIL. The graph showing the NRC curves is given in Fig. 3 [75].

The relative humidity of the air causes frequency-dependent sound absorption. It reaches its highest value when the frequency increases and for relative humidity in the range of 10 -30%. Below 4kHz, the worst moisture reduction corresponds to 0.1dB/m. The reduction coefficient (%) at 20°C relative humidity for frequencies between 2 kHz-12.5 kHz is given in Fig. 4 [76].

A different material developed is made of galvanized, stainless steel mesh and rock wool, providing a 19 dB reduction in sound pressure level. The related image is given in Fig. 5 [77].

In another study to reduce noise in generators, an ultrasonic design was made. In this design, a reduction in noise in the range of 12 dB(A)-20 dB(A) is achieved by using an acoustic sponge [78]. In another study carried out to reduce noise, a casing box in which the generator

**Figure 2.** Acoustic material in sponge structure [72]

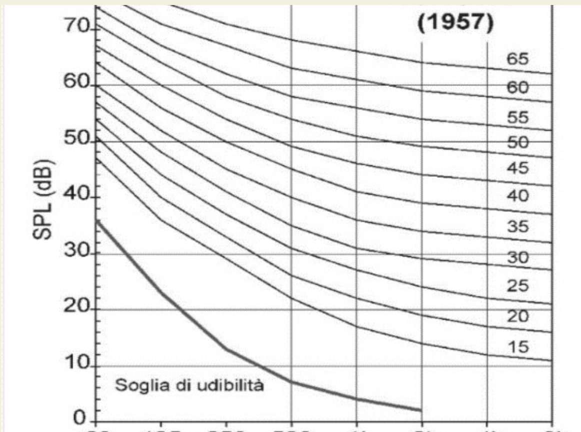


**Figure 3.** Graph showing NRC curves [75]

can be placed has been produced. When the inner surface of this box is also covered with an acoustic sponge, the noise is reduced by 75% in the 15-20 dB range [79]. It is also possible to place the generator in a closed environment. Standard modular acoustic panels, which are produced as closed boxes, are produced in various thicknesses and materials according to the noise control level to be provided. These materials are; It can be in the form of glass wool or mineral wool between the inner and outer steel material [80]. Ghorbani et al. (2016)'s work on reducing noise with generators working with natural gas, measurements were made by placing the generator in a 20 mm thick, steel-framed plywood material with elastomeric foam on its inner surface. Experimental operations were carried out with the generator in this box when its lid is open, with the simple enclosure

(SE), the semi-closed improved box (SME, the semi-covered modified enclosure) and the fully closed box (FME, fully covered modified enclosure). As a result of the operations performed by creating an air gap between the generator and the inner surface of the box, the generator sound level was 93.2 dB(A) for SE, 87.2 dB(A) for SME and 87.2 dB(A) for FME before acoustic measures were taken. It was determined to be 86.1 dB(A). Measurements were made at frequencies above 800 Hz for SE, and above 250 Hz for modified ones (SME and FME). Covering the generator with plywood is given in Fig. 6 [81].

Different processes can also be applied as passive methods. As can be seen in Fig. 7, the panel system can also be used to reduce/prevent noise [82].

Ölmez et al. In the study of (2019), a solid model with a thickness of 1.5 mm and outer surfaces of 3 mm was designed for the diesel generator in 3D and using a material such as a mesh, at frequencies of 63, 100, 125 and 160 Hz, vibration related noise points were generally found in the cooling air. It has been determined that it is concentrated in the entrances and exits, doors, sound-insulated enclosure upper surfaces, and also chassis upper surfaces. Due to this situation, the wall thickness of the outer structure was increased to minimize these noises [83]. In the study of Elancheliyan (2013), for two different generators with 360-kilovolt ampere (KVA) power, one of the diesel generators used in the construction sector, 360 (generator named G1) and 500 (generator named G2); at a distance of 1 m; 103.7 dB(A) for G1 and 104.3 dB(A) for G2, when this distance is increased to 10 m, 87.7 dB(A) for G1 and 90.1 dB(A) for G2, respectively. If there is an

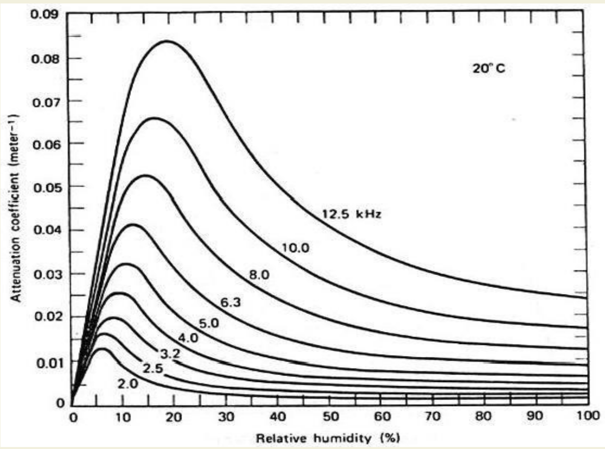


**Figure 4.** Reduction coefficient (%) at 20°C relative humidity for frequencies between 2 kHz-12.5 kHz [76]

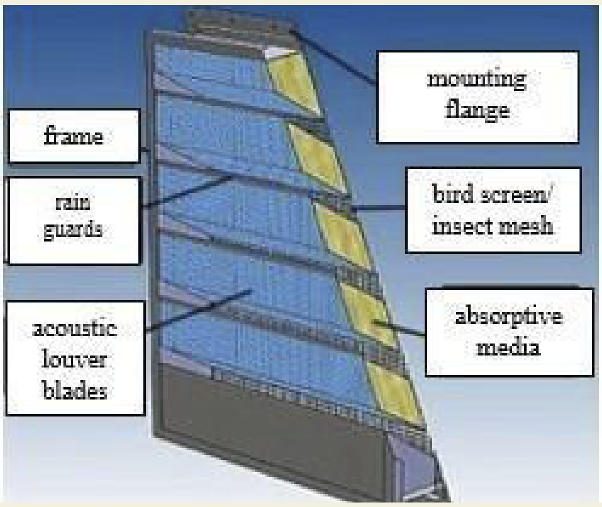


**Figure 5.** Design obtained from galvanized, stainless steel mesh and acoustic material [77]

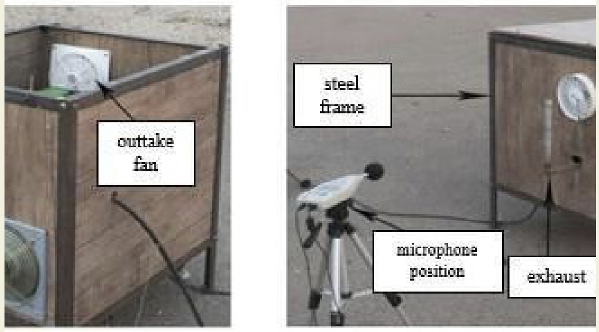


**Figure 6.** Covering the generator with plywood [81]

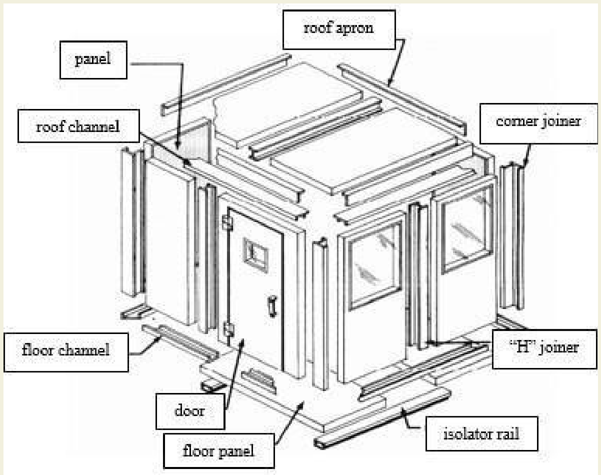


**Figure 7.** Panel system [82]

acoustic barrier between the generator, which is the sound source, and the measuring device, these values are; He determined that 87.6 dB(A) for G1 and 89.3 dB(A) for G2, when this distance is increased to 10 m, it is 79.9 dB(A) for G1 and 81.8 dB(A) for G2, respectively. This shows that the sound pressure level decreases as the distance to the generator increases [84].

## 2.5. Active Methods

Acoustic sensors, etc., are based on micro-electro-mechanical systems (MEMS) technology. Acoustic measurement applications are widely used in fields such as industrial, military, scientific and medical. It is also used in mass production and widely used in mobile devices such as laptops and smartphones, with lower cost and higher performance [85]. In addition, different applications have been developed for reducing the sound pressure level. By halving the number of sources, the sound pressure level is reduced by 3 dB(A). Accordingly, the change in sound pressure level is given in Fig. 8 [86].

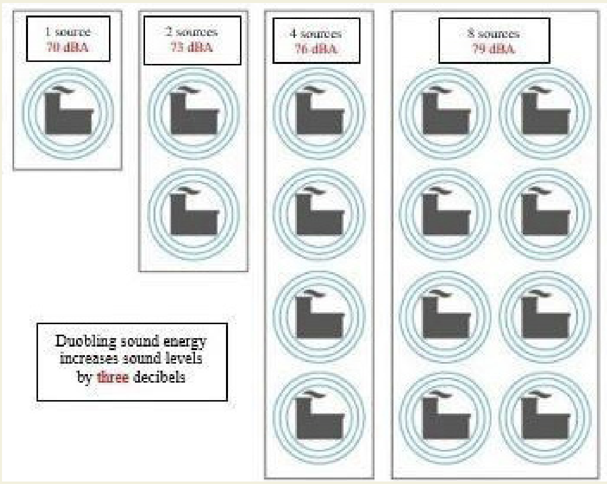


**Figure 8.** Change in sound pressure level when the number of sound sources is halved [86]

According to Figure 8, each generator produces a factory 70 decibels of sound. If a second generator is turned on next to this generator, the sound pressure level increases by 3 dB(A) to 73 dB(A). If the number of generators increases to four, the sound pressure level rises to 76 dB(A) [86].

According to Doğru (2016), the logarithmic average of daily personal noise exposure in diesel+electric trains and generator wagon (electricity) workers is 74.62 dB(A), this value is 77.1 dB(A) in generator wagons of mainline trains and 73.8 dB(A) on average in the region where the generator car workers are located. It has been stated that the noise can be reduced by about 30 dB at low frequency with the active noise method [87]. Another application inactive control methods is the use of silencers in the generator. In a study on this subject, pre- and post-design mufflers (old and new) were compared. Accordingly, although the measurement at a distance of 1 m was 120 dB at a distance of 1 m, a measurement of 109 at a distance of 2 m and 106 dB at a distance of 3 m in the old muffler, these values were obtained as 85 dB at a distance of 1 m, a measurement of 80 dB at a distance of 2 m and a measurement of 106 dB at a distance of 3 m. distance measurement was obtained as 70 dB. They obtained optimal results in the range of 1000-2000 Hz when a silencer was used [88]. In the study of Wei and Luo (2019), it was determined that the (A) weighted noise level in diesel generators was reduced from 92.2 dB to 59.7 dB with square mufflers [89].

Ishimitsu et al. (2000) stated that active control methods were preferred to reduce the vibrations between the wall and the ground due to the wave in their study on the ship, which is an environment other than the building [90].

The sound pressure level in the engine rooms of the ships is 110 -115 dB, which is the highest value compared to other sections, and it can cause hearing damage. To prevent this negative situation, the A-weighted sound pressure level of the engine has been reduced by 3 dB by designing mechanisms such as the use of low noise engine types (gas) and components, gear hammering, improved design of engine covers and engine top casing. With new designs, it is aimed to reduce it by 5 dB [91].

Vibration and noise were analyzed in generators that are also used in yachts and ships. In the study of Jordan and Elliott (2016), loudspeakers and microphones were used in the yacht cabin by increasing the control points from 7 to 19 in the application of the active noise control system, since noise and vibration are also disturbing for yacht manufacturers. The response to noise between speaker 1 and microphone 1 is given in Fig. 9 [92].

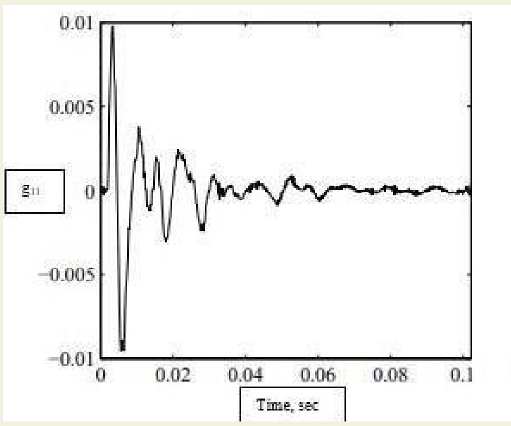


**Figure 9.** Response to noise between speaker 1 and microphone 1 [92]

As can be seen in Fig. 9, it can be seen from these results that the acoustic environment is relatively well damped with a reverberation time of about 180 ms and is characterized by multiple modes due to the size of the cabinet. As a result, it has been observed that the noise level can be reduced up to 23 dB at frequencies of 50 Hz and above [92]. Noise sources on a ship; diesel generator engine exhaust, ventilation inlet/outlet, pumps, cooling systems etc. known as. If the sound power level from the engine is 142 dB(A) (permissible value is 135 dB(A), the sound from the exhaust is 28 -35 dB, the sound power level of the coolers is approximately 90 dB(A), 25-30 dB for radial fans, for axial fans, this value is 25-35 dB. To reduce these sound levels, it has been suggested to reduce the noise-causing components and cover them with an insulating material from the outside [93]. Therefore, there are studies on this subject in the literature, one of which is the study of Bayraktar (2006) who stated that irregularity of the fan blades may affect the acoustic properties, therefore, the fan design can be effective by analyzing it with the Finite Element Method [94].

During the operation of generators, materials known as vibration wedges are used to prevent noise caused by vibration, which is one of the problems encountered. These materials prevent the formation of low-frequency noise caused by vibrations caused by unbalanced forces in the diesel engine [95]. In another study on the prevention of vibration, the sound level was measured as 108 dB at 50 Hz frequency in a generator with a maximum output power of 8 kVA (kilo volt-ampere). To reduce this noise level caused by vibration when an experimental study was conducted with insulating materials used in the form of three separate wedges at different angles to the engine, it was understood that the one placed at an angle of 90 ° was effective in preventing the noise caused by vibration [96].

In the study of Fuller (2012) on a portable (portable) generator with 2kW (kilowatt) power, to minimize the globally radiated noise, when working on active and passive noise control, sound pressure in the frequency range of 50-600 Hz It has been seen that a reduction of 10 -13 dB can be achieved at the level [97]. In another study on portable generators, the sound pressure level was reduced by up to 3 dB(A) by applying limited layer damping to the cooling fan cover to reduce noise. When precautions are taken in many parts of the generator, it has been determined that there is a decrease of 8.5 dB(A) in the sound pressure level [98]. To solve the noise problem in generators, the image of the silencer material used is given in Fig. 10 [99].

In the study, in which both active noise control and passive noise control were applied in the diesel generator, it was reduced between 5-10 dB by the feedback control method performed on a diesel generator with a power of 45 kVA (kilo volt-ampere, 36 kW). According to the feedforward control results obtained by using the acoustic reference sensor, it was observed that the sound pressure level was obtained on average 1.0 dB(A) and better results were obtained with the feedback method [100].

With the rapid advancement of technology in re-

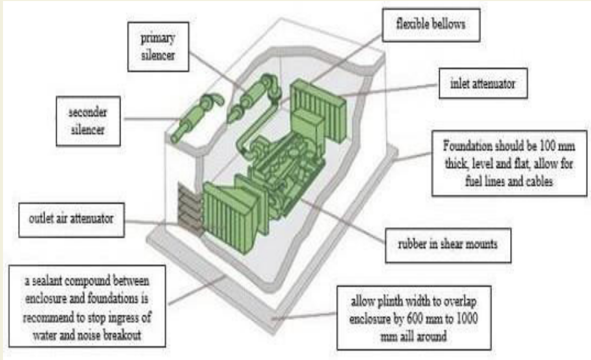


**Figure 10.** Using a silencer in the generator [99]

cent years, the variety of applications has increased. Regarding this, Gang et al. (2019) preferred to apply Vortex Generator (VG) Technology to the wind turbine blade in their study. In these turbines, it is requested that the sound pressure level should not exceed 44 dB when the sound speed is 8 m/s and 42 dB when the sound speed is 6 m/s. The maximum noise before adding VG is 107 dB, which corresponds to a frequency of 41 Hz (Hertz). After adding VG, the maximum noise is 83 dB, corresponding to a frequency of 45 Hz.

The sound pressure level decreases by approximately 20 dB at the frequency of 2000-4000 Hz [101]. In another study, it was stated that Acoustic Emission (with AE signals) methods could be effective in measuring vibrations caused by cylinder pressure of diesel engines [102]. According to the working principle, the noise factor can exhibit different behaviors. In this sense, it can be given as an example that electric vehicles differ from conventional internal combustion vehicles in terms of noise behavior, frequency and sound pressure level [103]. In addition, it is known that the noise in electric vehicles is less than that in internal combustion vehicles. In addition, in a study performed by producing artificial engine sound for the modification of acoustic characteristics, mechanical and combustion sounds were combined and an engine sound of gasoline and diesel vehicles were analyzed to reduce it by more than 10 dB after 1 kHz for diesel vehicles. Because as a result of the comparison, it has been determined that the diesel engine sound has a higher amount of noise after 1 kHz compared to the gasoline engine [104]. In another study by Narayan (2014), it was stated that the parameters that determine engine performance such as injection process, torque and power in diesel engines are controlled. For this, the use of filtering was preferred in the examination of injection effects by using air source motor acoustic signals and capacitors [105]. In addition to filtering, microphones can also be used in active noise and vibration control, while creating the second field of equal size, opposite to the first field [106]. According to these applied methods, there are differences in the amount of reduction in the sound pressure level. One of the examples that can begiven to this situation is the reduction in sound pressure level of at least 25 dB(A) by using a silencer in the exhaust [107].

According to the data obtained from the literature review, it has been seen that many methods can be applied by the design of the generators in noise control [108].

## 3. Results

By investigating how sensitive the human ear is to which frequencies, a chart called equal loudness contours has been developed [109]. The graph of Fletcher-Munson Loudness Curves is given in Fig. 11 [110]. It is known that an important factor regarding the speech tranmission index (STI) relates to the objective parameter of speech intelligibility for voice transmission channels. Robust ergonomics studies gain importance especially for "Special buildings" sensitive to sound characteristics. The private building is divided into 4 groups depending on the behavior and effectiveness against sound. While [AG1] shows "clave buildings" whose main function is directly related to sound, [AG2]; its main function is not related to sound, it is used as warning and guidance. [AG3]; the sound is considered as ambient noise. [AG4]; These areas are very sensitive to sound. Sound level control should be provided with special techniques.

Frequency analysis is very important for noise control in such buildings. In this article, buildings are divided into 5 groups for vibration [111].

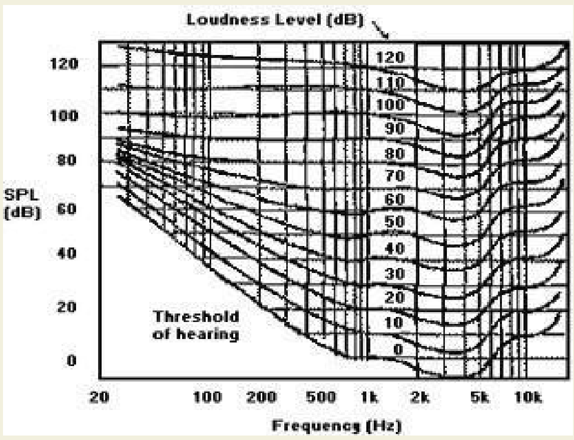


**Figure 11a.** Fletcher-Munson Loudness Curves [110]

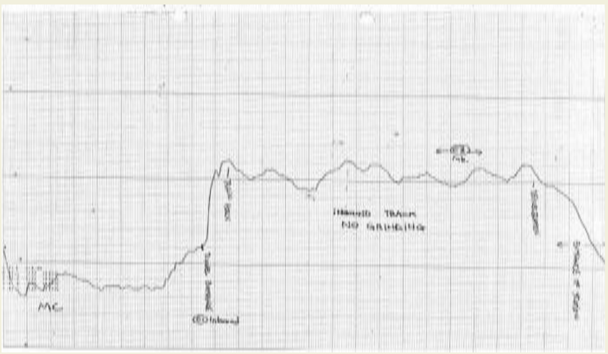

**Figure 11b.** SPL differences in terms of acceleration and deceleration period noise and vibration [112]

The Fletcher-Munson Loudness Curves plot shown in Figure 11a shows the human ear's perceptual capacities of sound pressure levels at different frequencies. For sound and vibration transmission from the ground, the acceleration and deceleration period according to the frequency, noise and vibration sound pressure level (SPL) difference of Ankara Metro Railway is analyzed and given in Fig. 11b.

The graph about the vibration and noise effects on the side buildings of the Ankara Metro Rail System and the ANKARAY Light Rail system line and the high noise and vibration caused by the subway rails at the entrance to the tunnel is given in Fig. 11 b, c, d. In this sense, especially the train horn, while the noise and vibration accelerate, but the noise and vibration decrease for the deceleration period [112].

In experimental studies on audio signals distorted by impact noise, efficient results can be obtained, especially for low noise ratios, when analyzes are made by suggesting algorithms [113].

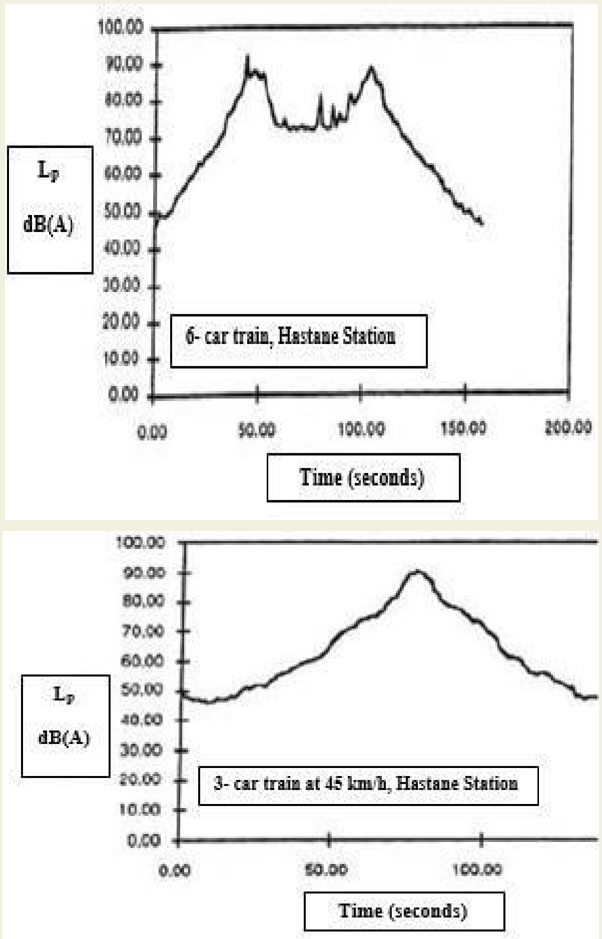


**Figure 11 c.**, d; The subway rails cause high noise and vibration at the entrance to the tunnel, and especially the train horn accelerates the noise and vibration, but the noise and vibration are also reduced for the on period [112]

Depending on the design and condition of a vehicle's suspension/damping system, the human body has different pain thresholds. Depending on the structure and condition of the vehicle's spring / shock absorber system, sometimes painful stress may occur in the human body. However, not only the spring/damping system but also other appropriate technical protection methods for the vehicle are important. The results measured during road movement of a truck are measured in Intermediate Bulk Container (IBC) vibration tests [114].

Working committees in some countries on noise are concerned with the standardization of test methods in building acoustics. In addition to national standardization, committees actively use their influence at the European and international level. In general, much of the low interest in industrial noise and standardization in the near future is concerned with the maintenance and updating of existing standards [115].

Hydroacoustic performance analysis was performed in open water conditions by applying the TVI (Type Vortex Index) technique to estimate the noise from tip eddy cavitation for a marine propeller. In this sense, the effects of blade number, cavitation number and propagation coefficient on the propeller tip eddy cavitation noise were investigated [116]

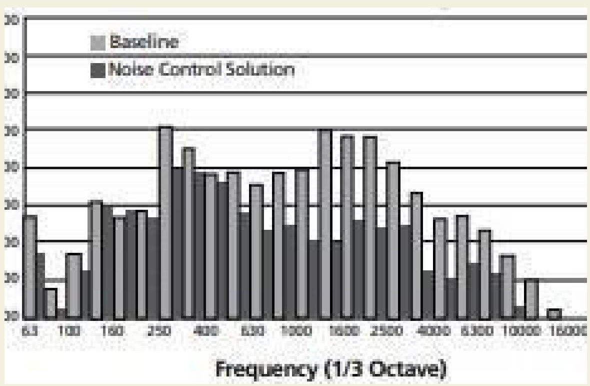


**Figure 12.** The sound pressure level obtained before and after using the acoustic barrier depending on the frequency [70]

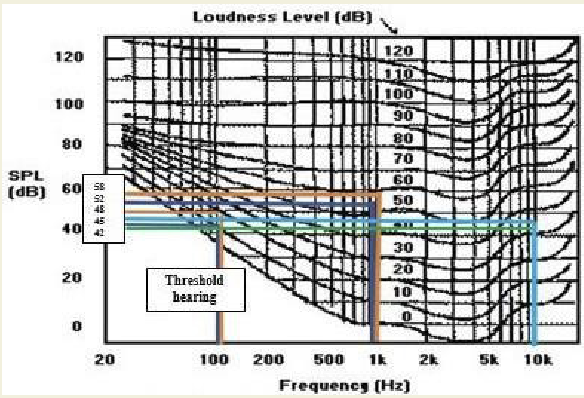


**Figure 13.** Comparison of the values obtained before and after using the acoustic barrier in the graph of Fletcher-Munson Loudness Curves

## 3.1. Example of Passive Method

The sound pressure values obtained before and after using acoustic barriers in sections such as air inlet, exhaust and heat output in most of the power generators are given in Fig. 12 [70].

According to Fig. 12, the sound pressure level, which was measured as 73.5 dB(A) on average, was obtained as an average of 67 dB(A) after this barrier was obtained, according to the measurements made at 8 different points before using an aluminized acoustic barrier on the polyester surface of the acoustic foam.

According to the data in Fig. 12, the sound pressure levels obtained at 100 Hz, 1k Hz and 10k Hz frequencies before and after using the acoustic barrier were compared, and the graph of Fletcher-Munson Loudness Curves is given in Fig. 13.

Sound pressure levels at 100, 1k and 10k Hz frequencies are shown in Fig. 13. According to Fig. 13; Before using the acoustic barrier, values of 48 dB at 100 Hz, 58 dB at 1k Hz, and 45 dB at 10k Hz were obtained. After using the acoustic barrier, it was obtained as 42 dB at 100 Hz and 50 dB at 1k Hz. It was observed that there was no perceived at 10k Hz. Depending on the barrier usage, the values obtained at different frequencies are given in detail in Table 2.

**Table 2.** Sound pressure levels according to frequencies before and after using acoustic barrier

| | Before Acoustic Barrier | | | After Acoustic Barrier | | |
|---|---|---|---|---|---|---|
| **Frequency (Hz)** | 100 | 1k | 10k | 100 | 1k | 10k |
| **Sound Pressure Level (dB)** | 48 | 50 | 52 | 42 | 0 | 0 |
| | 30 | 58 | 52 | 52 | 50 | 50 |
| | 10 | - | 45 | 0 | 0 | 0 |

According to this; before using the acoustic barrier, 48 dB at 100 Hz, 50 dB at 1k Hz, 52 dB at 10k Hz, 40 dB at 1k Hz and 30 dB at 10k Hz after acoustic barrier use. has been obtained.

## 3.2. Example of active method

The data in Fig. 14 were obtained when the noise of the engine exhaust of the generator with a power of 500 kW was measured in the frequency range of 25-2548 Hz, without using a muffler [88].

According to Figure 14, sound pressure levels are approximate without the use of a silencer; 113 dB at 30 Hz, 109 dB at 60 Hz, 119 dB at 90 Hz, 111 dB at180 Hz, and 105 dB at 270 Hz. The values obtained from the measurement results after using the silencer are given in Fig. 15 [88].

According to Fig. 15, the sound pressure levels are approximately; 71 dB at 30 Hz, 61 dB at 60 Hz, 45 dB at 90 Hz, 62 dB at 180 Hz, 58 dB at 270 Hz.

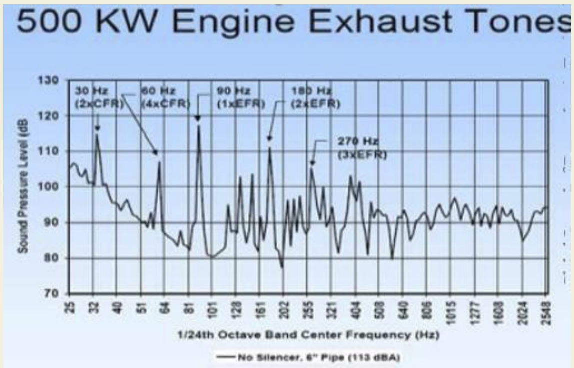


**Figure 14.** Frequency-sound pressure level graph obtained from the engine exhaust of 500 kW generator without using a silencer [88]

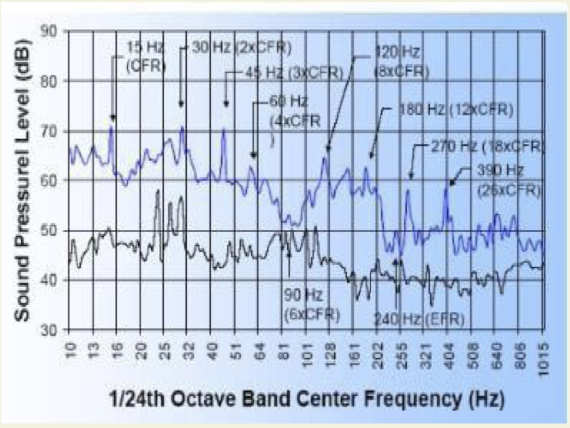


**Figure 15.** Frequency-sound pressure level graph obtained by using a silencer of the engine exhaust of a 500 kW generator [88]

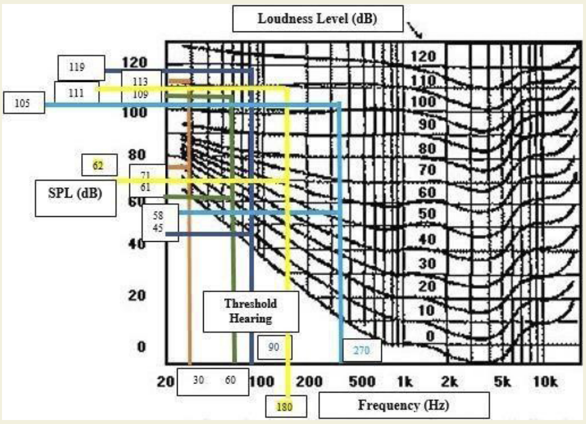


**Figure 16.** Comparison of the frequency values of the sound pressure values obtained before and after the muffler is installed in the Fletcher-Munson Loudness Curves graph

A comparison of the frequency values of the sound pressure values obtained before and after the muffler is installed in the Fletcher-Munson Loudness Curves graph is in Fig. 16.

Sound pressure levels at 100, 1k and 10k Hz frequencies are shown in Fig. 16. According to Figure 13; Before using the acoustic barrier, values of 48 dB at 100 Hz, 58 dB at 1k Hz, and 45 dB at 10k Hz were obtained. After using the acoustic barrier, it was obtained as 42 dB at 100 Hz and 50 dB at 1k Hz. It was observed that there was no perceived at 10k Hz. Depending on the barrier usage, the values obtained at different frequencies are given in detail in Table 3.

**Table 3.** Sound pressure levels according to frequencies before and after using acoustic barrier

| Frequency (Hz) | SPL (Sound Pressure Level) Before Acoustic Barrier, dB | | | | SPL After Acoustic Barrier, dB | | | |
|---|---|---|---|---|---|---|---|---|
| | SPL | 100 | 1k | 10k | SPL | 100 | 1k | 10k |
| 30 | 113 | 110 | 110 | 113 | 71 | 71 | 70 | 72 |
| 60 | 109 | 100 | 100 | 100 | 61 | 60 | 60 | 52 |
| 90 | 119 | 119 | 120 | 120 | 45 | 45 | 40 | 30 |
| 180 | 111 | 110 | 110 | 112 | 62 | 60 | 70 | 72 |
| 270 | 105 | 100 | 100 | 100 | 58 | 30 | 50 | 40 |

According to this; Before using the acoustic barrier, 48 dB at 100 Hz, 50 dB at 1k Hz, 52 dB at 10k Hz, 40 dB at 1k Hz and 30 dB at 10k Hz after acoustic barrier use. has been obtained. When the literature review is examined, silencer, acoustic sponge, glass wool etc. are used to prevent generator noise. It has been observed that materials with many sound-absorbing properties are used. As a result of the studies examined in this study, the measures taken to minimize the noise in the generator and the changes in the sound pressure level are given in Table 4.

When the data in the table are examined, it is seen that active and passive control methods are used. Although it is common to use a silencer in active methods, there is a need for improvement due to the intense fan noise. With the rapid progress of technology, felt, rock wool, etc., which have sound-absorbing and insulating properties. The use of materials is also increasing day by day. With the expansion of the product range, the preferability can be moved to better levels. As a result, more practical solutions can be developed to minimize noise.

## 4. Conclusions

In Table 2 given in the Results section, it has been observed that the sound pressure level in the generators is above 70 dB on average. This value varies according to the fuel type. In diesel generators, it was determined as 100-110 dB (92.2 dB in some models, 74 dB in diesel-electric generators, 93.2 dB in natural gas generators and 91.2-100.5 dB in electric generators).

The distance can also be effective in analyzing the noise factor in generators. Regarding this, noise levels for generators were determined to be 70 dB(A) at 7 meters and 80 dB(A) at 1 meter.

The above-mentioned values can be logarithmic or arithmetic, which is the perceived value of the human ear as a result of the measurements. Accordingly, it was obtained as 93 dB when measured logarithmically at a distance of

**Table 4.** Measures taken to minimize the noise in the generator and the amount of change in sound pressure level [52, 87, 88, 81, 66, 67, 92, 84, 93, 69, 58, 70, 89, 71, 98, 97, 72, 77, 99, 91, 101, 107]

| Sequence No | Product | Sound Pressure Level Before Action dB (A) | Action taken | Sound Pressure Level After Precautions dB (A) | Explanation |
|---|---|---|---|---|---|
| 1 | Diesel generator | 100-110 | - | - | One measurement at a distance of m |
| | | 5.8 | | | Noise exposure in the mainline engine room |
| 2 | Diesel+electric | 74.62 | Application of active control method | Approximately 30 dB reduction was achieved. | Generator car of the mainline trains |
| | | 77.1 | | | Generator car of the mainline trains |
| | | 73.8 | | | Region of employees |
| 3 | Generator | 1 m at 120, the second metric at 109, 3 mt at 106. | Using a silencer | 1 mt at 85, 2 mt at 80, 3 mt at 70. | - |
| 4 | In the natural gas generator | 93.2 | 930 * 670 * 2 mm thickness, 750mm 3 in size, plywood used for closing and acoustic foam box with ste-el-framed boxes | 88.4 | - |
| 5 | Generator | - | Rubber, fiber, polyurethane foam, wool felt, sand, cardboard, 32 mm thick sand layer | A reduction of 10 dB | - |
| 6 | Generator | Max.91.5-Min.76.3, decre-ase 15.2 | As a result of covering the generator with a textile material | Max.77.9- Min. 60.4, decre-ase 17.5 | While outdoors |
| 7 | The generator used on a luxury yacht | - | In case of active control | 50 Hz of over 23 dB 'e up is reduced. | - |
| 8 | Diesel generator | 1 mt from approximately 104 dB, 10 mt approxima-tely from 90 dB. | In the case of using barrier | 1 m from 89.3 to about 10 metric tons to about 80 from. | - |
| 9 | The generator used on board | - | To reduce these noises, it has been suggested to reduce the com-po-nents and to cover them with an acoustic material from the outside. | - | The noise level of the coolers is 90 dB (A), the Engine power level is 135 dB (A). |
| 10 | Generator | - | When using a quieter and less vibrating motor | In the amount of 10 dB reduction is achieved. | - |
| 11 | Electric generator | 91.2-100.5 | - | - | Gas emissions |
| 12 | Power generator | 73.5dB(A) | In the case of using the barrier obtained by using aluminized on the polyester surface of the acousti-c-foam. | 67dB(A) | - |
| 13 | Diesel generator | 92.2 | Design in the structure of the muffler. | 59.7 | - |
| 14 | Generator | - | In the case of an acoustic barrier made of glass wool around the generator. | If the height of the acoustic barrier is 0.9144 m, 72.8 is obtained, and if it is 3.66 m, 60 is obtained. If it is 10 meters, 14.1 dB reduction is achieved. | - |
| 15 | Generator | - | In case of damping operation to the cooling fan cover. | 3dB(A) reduction is achieved. | - |
| 16 | Generator | - | In the case of active-passive control operation . | 10-13dB(A) | - |
| 17 | Generator | - | In the case of using acoustic sponges of different thicknesses. | Approximately 80% until reduction is provided. | - |
| 18 | Generator | - | In the case of using galvanized, stainless steel mesh and rock wool material. | 19 dB (A) reduction is achieved. | - |
| 19 | Generator | - | In the case of using an acoustic reference sensor. | 1 according to the forward feed method, 5-10 according to the feedback method. | - |
| 20 | Generator | - | Different designs of engine covers. | A reduction of 3 dB was achieved. | - |
| 21 | Vortex Generator | In the 42-107 dB range. | In the case of different designs on wind turbine blades. | A reduction of up to 20 dB was achieved. | - |
| 22 | Generator | - | In the case of using a muffler on the exhaust. | Provide a minimum of 25 dB(A) is gone. | - |

7 m, and as 90.5 dB when measured arithmetically. It has been determined that the logarithmic measurement of the sound pressure level gives healthier results.

In the material method section, the definition of generators and the noise they produce are given. Acoustic solutions are analyzed under the heading of active and passive methods.

When passive methods are examined in Chapter 2, it is seen that the values measured as approximately 104 dB at a distance of 1 m (meter) and 90 dB at a distance of 10 m are reduced to 89.3 and 80 dB, respectively, in the case of using a barrier. This provides significant advantages. In case the natural gas generator is closed with a 2 mm thick plywood and steel framed box and acoustic sponge is used in this box; the sound pressure level is from 93.2 to 88.4 dB, (approximately 4.8). Rubber, fiber, polyurethane foam, wool felt, sand, cardboard, the barrier obtained as a 32 mm thick sand layer is 10 dB when the generator is closed with a textile material, the values are 60.4, 76.3-91.5 (the difference between the minimum-maximum values is 15.2 dB). It can be reduced from 73.5 dB (A) to 67 dB (A) if a barrier is formed on the polyester surface of the acoustic foam by using aluminized. It has been understood that if a different acoustic sponge is used, it can be reduced by 80%.

When the active methods are examined in Chapter 2, it is 92.2 to 59.7 dB with the design made in the silencer used in the diesel generator, 3 dB (A) with the damping process on the cooling fan cover, 10-13 dB (A) in the case of active-passive control, acoustic reference 1 according to the forward feed method, 5-

10 dB according to the feedback method, 3 dB with different design of engine covers, 20 dB in case of different designs in Vortex Generator, wind turbine blades, minimum 25 dB(A) in case of using silencer in exhaust amounts were decreased.

In diesel-electric generators, with the application of active control methods, approximately 30 dB, in case of using a silencer, values that are 120 at 1 m, 109 at 2 m, 106 dB at 3 m, 85 at 1 m, 80 at 2 m. It has been understood that it can be reduced to 70 dB at 3 meters, 3 dB with the different design of the engine covers, 10 dB with the use of a quieter and less vibrating engine, and 20 dB with the different designs of the wind turbine blades in theVortex Generator.

According to these results, it has been seen that it is reduced by approximately 36 dB by using a silencer compared to active control methods, therefore it is a more successful method. Because, by using mufflers in sections where noise is intense, such as exhaust, a reduction in sound pressure level up to 25 dB can be achieved. In addition, no disadvantages of the silencer in terms of human health were encountered.

It has also been concluded that materials such as acoustic-sponges, which are preferred in passive control methods, are not as effective as active methods in terms of sound pressure level. In addition, while the use of acoustic sponges with a porous structure and sound absorption capacity, which are described as open cells, provides an advantage, it can be a disadvantage dueto its synthetic content. Because in nature, nature-friendly and recyclable materials can be preferred to reduce carbon gas emissions from artificial materials.

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