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# Design and Performance Evaluation of a Soundproof Enclosure for a 2.5kVA Generator

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**ABSTRACT:** The high level of noise that radiates from domestic generators in most parts of the neighbourhoods in Nigeria is becoming very much uncomfortable and constitutes nuisance to public serenity thereby creating noise pollution. This paper reports the design and performance evaluation of a soundproof enclosure for a 2.5 *kVA* generator. The purpose of this work was to reduce the sound pressure level (*SPL*) of the generator from a control value of 102 *decibel* to a comfortable noise level of about 86 *decibel* at a distance of 4 *m*. Material selection was done based on absorptivity, sound reduction coefficient of acoustic materials and the sizing of the absorber was done to determine the thickness required for lining the enclosure. Panel made of steel and sound absorbing material were used to control the noise propagation at its transmission path. Performance test of the soundproof device was carried out and *SPL* from the generator before and after the application of the enclosure were measured. This reveals a sound attenuation of 9.5, 12.9, 11.6, 12.2, 15.1, 14.5, and 15.5 *dB* at distances of 0.6, 1.2, 1.8, 2.4, 3.0, 3.6, 4.2 m respectively by using mineral wool with a noise reduction coefficient (*NRC*) of 0.78.

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Sound is produced when an object vibrates in open air and the process emits pressure waves into the air. The decibel (dB) scale defines the level of sound and this scales are from 80 to 100 (very loud), 100 to 125 dB (uncomfortable) and 140 dB (threshold of pain). According to Chandrashekara *et al* (2014) noise is an unwanted sound. Absorbing sound spontaneously converts part of the sound energy to a very small amount of heat in the intervening object (the absorbing material), rather than the sound being transmitted or reflected. The Maximum permitted overall noise levels range from 45 dB to 72 dB, depending on location and zoning. Since untreated generator set noise levels can approach 100 dB or more, both the location of the generator set and noise mitigation takes on great importance. Soundproofing is any means of reducing the sound pressure with respect to a specified sound source and receptor. There are several basic approaches to reducing sound which includes: increasing the distance between source and receiver, using noise barriers to reflect or absorb the energy of the sound waves; using damping structures such as sound baffles, or using active anti-noise sound generators (Fahy, 2001). Soundproofing can suppress unwanted indirect sound waves such as reflections that cause echoes and resonances that cause reverberation (Tandon and Nakra, 1999). According to Delany and Bazley (1970), acoustic quieting, noise mitigation and noise control can be used to limit unwanted noise. Generators produce high level of noise and vibration whether they run continuously in power applications or only occasionally in standby mode. Sources of generator noise include engine noise, Cooling fan noise, alternator noise and induction noise. Others are engine exhaust and structural/mechanical noise (Tandon and Nakra, 1999). Sound can become painful, uncomfortable or a nuisance when the amplitude of the pressure wave exceeds the threshold level. Ideally, the noise should not exceed 60dB at 3 meters. Ambient sound levels exceeding 60-70 dB can be regarded as noise pollution, which leads to significant health problems such as depression and most commonly, loss of hearing (Mikolajczyk and Cieslewicz, 1982). Craik (2003) presented a model for computing coupling loss factor in the prediction of sound transmission through lightweight double walls, in which Sound attenuation is needed to meet local noise ordinances or reduce impact on employees or neighbors. A reverberation room method was used by Kuku *et al* (2012) to measure the noise absorption efficiency of a soundproof enclosure using a 950 Watts/220 Volts rated generator to ascertain the enclosure performance average at 76.40% noise absorption. Akhaze (2016) developed a soundproof device and carried out a

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performance evaluation of the device which revealed a reduction of sound pressure level by 7.64, 6.24, 6.82, 8.72 and 8.68 *dB* at distances of 0.70, 1.40, 2.10, 2.80 and 3.50 *m* respectively from the generator. Hammad *et al* (2013) carried out a research work which focused on how generator noise is propagated, controlled and reduced to a limit as defined by domestic laws. Belanger (2016) investigated various materials and configurations that will minimize noise output upon repetitive impact, the results could be beneficially implemented for various applications including impact stops in production facilities where each stop is hit hundreds of times per minute contributing to high decibel levels on the production floor. The aim of this work was to design and carry out performance test of a soundproof enclosure for the purpose of attenuating the sound radiating from a 2.5 kVA generating set mostly used at residential apartments and small business centres as alternative source of electricity supply in Nigeria.

## MATERIALS AND METHOD

Noise control at its transmission path is accomplished through the installation of acoustic barriers and the use of insulation. Material selection for the insulation of the soundproof is based on noise reduction coefficient which is a common parameter used for measuring sound absorption of a material. It is defined as the ratio of energy absorbed by a material to the energy incident upon its surface. Table 1 shows the noise reduction coefficient (percentage of sound that a surface absorbs) of various acoustic materials that can be used for soundproofing purposes. Mineral wool is selected for this work because it has a high sound absorption coefficient of 0.78.

**Table 1:** Noise reduction coefficient of selected acoustic materials

| Material | Noise reduction coefficient |
|---|---|
| Plywood | 0.23 |
| Foam rubber | 0.56 |
| Cork (wall tiles) | 0.70 |
| Mineral wool | 0.78 |

*Determination of the drop in decibel***:** To determine the decibel drop (*dB*) of the absorption material at a given frequency, the coefficient of sound reduction (*C*) in equation 1 is used.

$$C = 1 - 10^{\left(-\frac{dB}{20}\right)} \qquad (1)$$

*C* = Coefficient of sound reduction; *dB* = Decibel drop

$$\therefore dB = -20\, log_{10}^{(1-C)}$$
$$= -20\, log_{10}^{(1-0.78)} = 13$$

*Determination of heat released from combustion of fuel (petrol) in the generator:* The heat released from the combustion of petrol is given by equation 2

$$Q_c = \dot{m} \times C = \rho V \times C_v \qquad (2)$$

$\dot{m}$ = Mass flow rate of fuel (kg/s); ρ = Density of fuel (kg/m$^3$); $C_v$ = Calorific value of fuel (kJ/kg); $Q_c$ = Heat released from combustion (W)

$$\therefore Q_c = \frac{1.2 \times 737 \times 44 \times 10^6}{3600 \times 1000} = 10809.33\text{W}$$

*Heat loss to exhaust gas:* Heat loss to exhaust gas = $Q_L$ = 60% of $Q_c$

$$\therefore Q_L = 0.60 \times 10809.3 = 6485.58\text{W}$$

*Energy available in the generator engine:* The energy available in the generator engine = $Q_A$ = 40% of $Q_c$

$$\therefore Q_A = 0.4 \times 10809.3 = 4323.72\text{W}$$

*Determination of heat generated within the soundproof enclosure:* The heat produced in the soundproof enclosure ($Q_e$) is given by equation 3

$$Q_e = Q_A - Rated\ power\ of\ generator\ on\ full\ load \quad (3)$$
$$(Q_e) = 4323.72 - 2500 = 1823.72W$$

*Selection of the fan:* Heat generated in the enclosure has to be extracted using an induced draft fan. The volumetric flow rate of the air needed for removing the heat is given by equation (4)

$$V_f = \frac{\dot{m}}{\rho_a} = \frac{Q_e}{C_p \Delta T \rho_a} \ldots\ldots (4)$$

$V_f$ = Volumetric flowrate of air (m$^3$/s); $\rho_a$ = Density of air; $C_p$ = Specific heat capacity of air a constant pressure; $\Delta T$ = Temperature difference between ambient air and air in the enclosure

$$V_f = \frac{1823.72}{1.0 \times (70 - 32) \times 1.029} = 0.04664\ m^3/s$$

Hence, the fan for extracting hot air from the enclosure was selected based on the volumetric flow rate of air which has been determined to be 0.04664m$^3$/s.

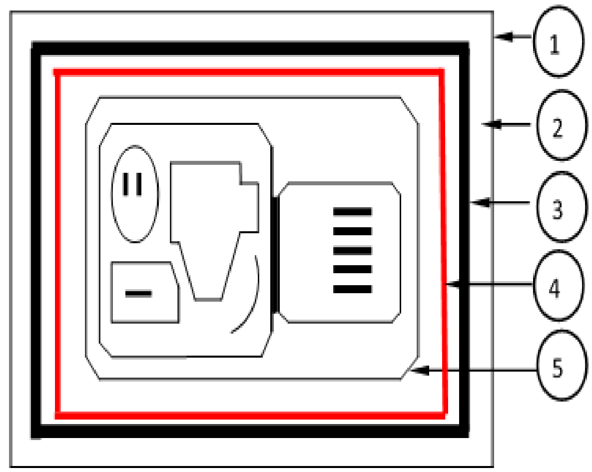
*Fabrication:* The fabrication of the soundproof enclosure measuring 0.9 m x 0.78 m x 0.72 m was done using mild steel sheet of 2 mm thickness and this was carried out at the Mechanical Engineering

Department of the Niger Delta University Bayelsa State.

**Fig 1**: Front view of enclosure

**Fig 2**: Back view of enclosure

The inside of the enclosure was lined with a 15 mm thick mineral wool (sound absorber) and padded with 5 mm thick plywood. A flexible pipe is connected to the generator exhaust pipe to dissipate the exhaust gas into the atmosphere. An induction fan was installed to extract heat from the enclosure and dispel to the surrounding. Figure 1 and 2 show the front and back views of the prototype sound proof enclosure housing the generator set while Figure 3 shows schematic diagram of the generator set inside the soundproof enclosure




Key: 1= Steel enclosure; 2= Trapped air, 3= Mineral wool, 4= Ply wood, 5= Generator set,

**Fig 3:** Schematic diagram of the generator set inside soundproof enclosure

## RESULTS AND DISCUSSION

A 2.5 kVA Honda generator was operated and placed inside the sound proof enclosure and allowed to run for 25 minutes in order to assess the performance of the enclosure. A sound level metre with a measurement range of 30 to 130 dB was used to measure the sound pressure level at various distances which were recorded in Table 2. It was observed that the noise level from the generator was very high when placed in an open environment reading as high as 102.1 dB at a distance of 4.2 m.

**Table 2:** Measurement of sound pressure level with and without sound proof enclosure

| S/N | Distance (m) | Without enclosure (dB) | With enclosure (dB) | Reduction in sound level (dB) |
|---|---|---|---|---|
| 1 | 0.6 | 113.5 | 104.0 | 9.5 |
| 2 | 1.2 | 111.2 | 98.3 | 12.9 |
| 3 | 1.8 | 109.2 | 97.6 | 11.6 |
| 4 | 2.4 | 107.3 | 95.1 | 12.2 |
| 5 | 3.0 | 105.4 | 90.3 | 15.1 |
| 6 | 3.6 | 103.9 | 88.5 | 14.5 |
| 7 | 4.2 | 102.1 | 86.6 | 15.5 |

However, when the generator was placed inside the sound proof enclosure the Table reveals a significant reduction in sound level between 12.2 dB and 15.5 dB at varying distances of 2.4 m and 4.2 m respectively, which in most cases are the distances generator sets are placed from residential buildings. This result agrees with some of the findings reported by some acoustic researchers such as Kuku *el ta* (2012) that developed a sound proof enclosure that can reduce noise by as much as 20%.

*Conclusion*: The use of mineral wool and plywood as insulation absorbers has been proofed to be very effective as they can reduce sound coming from a 2.5 kVA generator set by 15.5 dB at a distance of 4.2 m, which is a moderate noise level at that distance. Hence, reducing the noise pollution generated in many neighborhood and eliminating earing health hazard. The use of some other types of insulation absorbers can be used to further the research work in this field.

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