Parvathi, K. and A. Navaneetha Gopalakrishnan "Studies On Control Of Noise From Portable Power Generator" in Martin J. Bunch, V. Madha Suresh and T. Vasantha Kumaran, eds., *Proceedings of the Third International Conference on Environment and Health, Chennai, India, 15-17 December, 2003*. Chennai: Department of Geography, University of Madras and Faculty of Environmental Studies, York University. Pages 328 – 338.

STUDIES ON CONTROL OF NOISE FROM PORTABLE POWER GENERATOR

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Abstract

Portable power generators are used very commonly in shops, offices and homes today in order to supply power during power shutdowns. These generators emit very high levels of noise, in addition to noxious air emissions. Exposure to noise causes detrimental effects on neuro-endocrine, cardiovascular, respiratory and digestive systems. Chronic exposure to noise causes fatigue and interferes with concentration, thus reducing work efficiency.

Experimental studies on the assessment and control of indoor and near-field noise levels due to the operation of a portable power generator were undertaken at the Centre for Environmental Studies (CES), Anna University. Noise control was studied employing anti-vibration mounts (made up of rubber, coir, polyurethane foam, thermocole, wool–felt and sand bed) and enclosures (made up of cardboard, thermocole and a sandwich of cardboard and thermocole).

The sand beds of 32mm thickness (containing sand particle size 0.5 mm) with an air gap of 5 cm between sandwich enclosure walls, among anti-vibration mounts and enclosures, respectively, were found to be most effective in controlling noise due to the generator operation.

INTRODUCTION

Portable generators are used very commonly in shops, offices and homes today in order to supply power during power shutdowns. These generators emit very high levels of noise, in addition to noxious air emissions. The noise may be generated by aerodynamic effects or due to forces that result from combustion process or may result from mechanical excitation by rotating or reciprocating engine components [6]. Noise levels due to the operation of a 2 KVA capacity portable generator, at different distances inside and outside a laboratory, have been assessed [14].

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Studies show that heart rate and patterns of diurnal rhythm were altered significantly in free-moving rhesus monkeys exposed to a community noise recording 12 hours per day for 7 weeks [13]. In cross-sectional studies, it was found that road traffic noise exposure increases the risk of myocardial infarction and total ischemic heart disease [11]. Audiometric examinations conducted over the period from 1996 to 1999 on industrial workers showed that 27.8% suffered some hearing damage while 7.7% suffered serious hearing loss [5]. Noise interferes with work tasks as well as speech communication. It affects inter-room privacy and interferes with sleep, especially the rapid eye movement stage. Annoyance and irritation are direct consequences of prolonged exposure to noise [18]. Noise causes a stress reaction and lowers morale. Chronic exposure to noise causes fatigue and interferes with concentration, thus reducing work efficiency [12].

A study [17] on noise control from portable generators has been conducted employing damping layer treatments (using PVC sheet and mild steel) and partial enclosures (using sandwich of thermocole and foam). Studies [3, 4] on active control and also optimization of the active control system (steel wall panels) for exhaust noise control from an enclosed generator have been conducted. The Indian Standard IS: 3483 (1965) [7] recommends vibration isolators made of resilient materials like steel springs, rubber, cork and felt. The effect of using granular material 1 mm diameter balls of steel, aluminium, zirconium and tetra flouro ethylene resin-coated steel has been evaluated [16]. The damping efficiency of 6 mm diameter made of lead, steel and acrylic resin in a horizontally vibrating system has also been studied [15]. The Central Pollution Control Board [1] recommends a 1.6 mm thick mild steel plate for the fabrication of the acoustic enclosure for a diesel generator set for insertion loss of up to 30 dB(A).

NOISE STANDARDS IN INDIA

The Acceptable indoor noise levels for various types of buildings as per the Indian Standard IS: 4954-1968 [9] and Indian ambient noise standards as specified by the Central Pollution Control Board, India [2], and are detailed in Table 1 and Table 2, respectively.

Table 1: Acceptable Indoor Noise Levels for Various Types of Buildings (Indian Standard IS: 4954-1968) [9]

Sl. No.	Location	Noise Level [dB(A)]
1	Radio and T.V. studio	25-30
2	Music room	30-35
3	Hospitals, **classrooms, auditoria**	**35-40**
4	Apartments, hotels, homes, conference rooms, small offices	35-40
5	Court rooms, private offices, **libraries**	**40-45**
6	Large public offices, banks, stores	45-50
7	Restaurants	50-55

Table 2: Indian Ambient Noise Standards [2]

Area Code	Category of Area	Limit in dB(A) , L_{eq}	
		Day time	Night time
A	Industrial area	75	70
B	Commercial area	65	55
C	Residential area	55	45
D	**Silence Zone**	**50**	40

Note:

1. Day time is reckoned in between 6 a.m. and 9 p.m.
2. Night time is reckoned in between 9 p.m. and 6 a.m.
3. **Silence zone is referred to as areas up to 100 metres around such premises as hospitals, educational institutions and courts.** The Silence zones are to be declared by the Competent Authority. Use of vehicular horns, loudspeakers and the bursting of crackers shall be banned in these zones.
4. Mixed categories of areas should be declared as one of the four above mentioned categories by the Competent Authority and the corresponding standards shall apply.

TEST SETUP AND INSTRUMENTATION

The portable generator of 550 VA capacity (rated AC output of 450 VA), with a 4-stroke S.I. engine and alternator was used in the study. It is manually petrol-started and kerosene-run and is used to supply power to the auditorium during power shutdowns. It has dimensions 42 cm x 35 cm x 33 cm.

The equipment used to measure noise levels was a hand-held sound level meter (Model: SLM 340; Make: M/s AZ Instruments, Germany) which measures the sound level via its built-in capacitor microphone and displays it on a digital LC display, with a resolution of 0.1 dB.

Standard test sieves (Make: M/s Malhotra Brothers, Bangalore) were used to assess the particle diameter of the sand used for the sand bed (anti-vibration mount). The sieves with pore sizes in the range of 2300 microns to 37 microns were used. An electrical rotary sieve shaker was used to sieve the sand.

METHODOLOGY

Assessment of Indoor Noise Levels

The source of noise (portable generator) was placed at its usual location of operation, i.e., at a distance of two metres from the outside of the auditorium entrance II (L_{1b}). The A-weighting network and fast response mode of the sound level meter were used. The measurements were made at a height of 1.2–1.5 m above the floor [10]. The measurements were made at the places of annoyance [10] namely, at selected locations near the entrance (doors) of the auditorium (L_{1a} and L_{1b}), library (L_2) and three classrooms (L_{3a}, L_{3b}, L_4, L_5). The locations of the sampling points are depicted in Figure 1.

The indoor noise levels measured were averaged over $\pm$ 0.5 m of each of at least three positions [10]. The measurements were made under the loading conditions of idling and rated full load (460 W). The measured indoor noise levels were compared with the acceptable indoor noise levels specified for auditoria, libraries and classrooms [9].

Near-field Noise Level Measurements

The near-field noise level measurements were conducted at a 1m distance from the generator [8]. The study was conducted for 1 hour and the readings were taken at 10 minute intervals. The equivalent noise levels were calculated. The measured equivalent noise levels were compared with the 50 dB(A) daytime ambient noise standard prescribed in India for a silence zone [2].

Effect of Anti-Vibration Mounts on Indoor Noise Levels

The normal position of the anti-vibration mount was between the machine and its foundation [7]. The noise levels due to the generator operation, after application of different anti-vibration mounts in the form of rectangular pads, were assessed in the same locations and generator loading conditions, as detailed previously. The performance of thermocole, polyurethane foam, rubber, wool-felt, coir and sand as materials for use anti-vibration mounts to reduce noise was studied. The size of the anti-vibration mount was 61 cm x 38 cm.

The effect of two thicknesses of anti-vibration mounts was studied. The effect of varying the particle size of the sand (0.15 mm and 0.5 mm) was also studied.

Effect of Enclosures on Indoor Noise Levels

Tight-fitting, leaky, rectangular enclosures were employed for control of noise due to the generator. The enclosures were leaky because of escape of noise from the exhaust opening, air intake openings and openings for the pulley. The openings were provided as the generator engine is an air-cooled engine. In addition, while operating the generator under 460 W load condition, another opening was provided for drawing the load. All the dimensions of the openings were based on the dimensions of the components of the generator.

The effect of varying the size of the enclosures, and maintaining a constant wall thickness, was studied. Also, the effect of varying the wall thickness of the enclosures, maintaining the size constant, was studied. The effect of varying the thickness of air gap between enclosure walls was also studied. The details of enclosures used in the study are detailed in Table 3.

Table 3: Details of Enclosures

Material of enclosure	Size of enclosure (‘L’ cm x ‘B’ cm x ‘H’ cm)	Wall thickness (mm)	Enclosure Type
Cardboard	47 x 40 x 38	5	E-1
	47 x 40 x 38	7	E-2
	49.5 x 42.5 x 40.5	7	E-3
	52 x 45 x 43	7	E-4
Thermocole	47 x 40 x 38	10	E-5

	47 x 40 x 38	16	E-6
	49.5 x 42.5 x 40.5	16	E-7
	52 x 45 x 43	16	E-8
Sandwich (of cardboard and thermocole)	47 x 40 x 38	17	E-9
	47 x 40 x 38	23	E-10
	49.5 x 42.5 x 40.5	23	E-11
	52 x 45 x 43	23	E-12

RESULTS AND DISCUSSION

Indoor Noise Levels due to Portable Generator Operation

The indoor noise levels due to the portable generator operation were assessed and compared with the acceptable indoor noise levels [9]. The maximum indoor noise level in the auditorium and library were 75.2 dB(A) and 71.8 dB(A), respectively, when the generator was operated under 90% load (460W). The impact of the generator noise was maximum outside the Classroom II in the order of 68 dB(A) when the generator was operated under 90% load (460W). The minimum indoor noise levels in the auditorium, library and classrooms were 66 dB(A), 69.4 dB(A) and 54.2 dB(A), respectively when the generator was operated under 90% load condition.

These results showed that the indoor noise levels were not acceptable according to IS: 4954 (1968) [9]. This standard specifies acceptable indoor noise levels of 35–40 dB(A) for auditoria and classrooms and 40–45 dB(A) for libraries. Hence, control of noise levels due to the generator operation was found necessary. The indoor noise levels due to the portable generator operation are detailed in Table 4.

Table 4: Indoor Noise Levels due to the Portable Generator Operation

Selected locations @			Indoor noise levels [dB(A)] Loading conditions of generator: Idling	460 W load	Acceptable indoor noise levels [dB(A)] according to IS: 4954 – 1968 [9]
Auditorium	L_{1a}	1	62.1	66.0	35-40
		2	65.5	69.6	
	L_{1b}	3	69.4	73.9	
		4	71.9	75.2	
Library	L_2	5	64.9	69.4	40-45
		6	67.3	71.8	
Classroom I	L_{3a}	7	50.4	54.2	35-40
		8	54.2	58.1	
	L_{3b}	9	51.7	55.6	
		10	55.7	59.8	
Classroom II	L_4	11	62.4	66.2	
		12	64.8	68.0	
Classroom III	L_5	13	57.3	61.5	
		14	59.2	63.3	

@ as depicted in figure 1

Effect of Anti-Vibration Mounts on Indoor Noise Levels

The performance of various materials for use as anti-vibration mounts to reduce noise was studied. The effect of thickness of the anti-vibration mounts was studied. The materials used as anti-vibration mounts were rectangular pads of thermocole, polyurethane foam, rubber, wool – felt, coir and granular material (sand bed).

All the anti-vibration mounts studied had the same dimensions of 61 cm x 38 cm. The noise reduction due to the rubber and wool-felt pad were similar, as was the case with the coir pad and sand bed with a sand particle size 0.15 cm. From the results, it can also be seen that for every doubling of thickness, there was a reduction of 2 dB(A) in noise levels. The extent of reduction in noise levels using the various anti-vibration mounts is detailed in Table 5. The effect of anti-vibration mounts on indoor noise levels is depicted in Figure 2.

Table 5: Extent of Reduction in Noise Levels due to Anti-vibration Mounts

Specification of Anti-vibration Mounts		Extent of Reduction in Noise Levels [dB(A)]
Thermocole pad (61cm x 38 cm)	$t^{\#}$ = 16.34 mm $t^{\#}$= 32.68 mm	2-3 4-6
Polyurethane foam pad (61cm x 38 cm)	$t^{\#}$ = 16.22 mm $t^{\#}$ = 32.44 mm	2-3 5-6
Rubber pad (61cm x 38cm)	$t^{\#}$ =16.14 mm $t^{\#}$ = 32.28 mm	2-4 5-6
Wool-Felt pad (61cm x 38 cm)	$t^{\#}$ =16.42 mm $t^{\#}$= 32.84 mm	4-5 6-7
Coir pad (61cm x 38cm)	$t^{\#}$= 16.32 mm $t^{\#}$ = 32.64 mm	6-9 8-10
Sand bed (61cm x 38 cm) (Particle size=0.15mm)	$t^{\#}$ = 16 mm $t^{\#}$ = 32 mm	6-8 8-10
Sand bed (61cm x 38 cm) (Particle size=0.5 mm)	$t^{\#}$ = 16 mm $t^{\#}$ = 32 mm	7-9 10-12

$^{\#}$t = thickness of pad in mm

Effect of Enclosures on Indoor Noise Levels

The performance of different sound-absorbing materials for use as enclosures to reduce noise, was conducted. The effect of two sizes as well as two wall thicknesses of the enclosures was studied. The effect of two thicknesses of air gap between enclosure walls was also studied. The materials used for the enclosures were cardboard, thermocole and a sandwich of both cardboard and thermocole.

The wall thickness of enclosures was varied, maintaining the size constant and the effect was studied. Between cardboard enclosures E-1 and E-2, increasing the wall thickness by 2 mm, a reduction of 2 dB(A) was observed, whereas, among thermocole enclosures E-5 and E-6, increasing the thickness by 6 mm, a further reduction of 3 dB(A) was observed. Using sandwich enclosure E-9, a reduction of 13 dB(A) was observed, whereas, using sandwich enclosure E-10, a reduction of 19 dB(A) was observed.

The size of the enclosures was varied, leaving the wall thickness constant and its effect was studied. Using cardboard enclosure E-2, a reduction of 9 dB(A) was observed. Increasing the size of the enclosure on all sides by 5 cm, a further reduction of 3 dB(A) was observed, i.e., using cardboard enclosure E-4, a reduction of 12 dB(A) was observed. Using thermocole enclosure E-6, a reduction of 13 dB(A) was observed. Increasing the size of the enclosure on all sides by 5 cm, a further reduction of 2 dB(A) was observed, i.e., using thermocole enclosure E-8, a reduction of 15 dB(A) was observed. Using sandwich enclosure E-10, a reduction of 19 dB(A) was observed. Increasing the size of the enclosure on all sides by 5 cm, a further reduction of 2 dB(A) was observed, i.e., using sandwich enclosure E-12, a reduction of 21 dB(A) was observed.

The performance of air gaps as a sound absorbing medium was investigated to reduce the noise. Doubling the thickness of the cardboard enclosure air gap, a reduction of 2 dB(A) was observed, whereas, when the air gap thickness of thermocole enclosures was doubled, a reduction of 3 dB(A) was observed. Using an air gap of 2.5 cm and 5 cm between sandwich enclosure walls, a reduction of 25 dB(A) and 28 dB(A), respectively, was observed.

The extent of reduction in noise levels due to enclosures is detailed in Table 6. The effect of enclosures on indoor noise levels is depicted in Figure 3.

Table 6: Extent of Reduction in Noise Levels due to Enclosures

Specification of Enclosures			**Extent of Reduction in Noise Levels [dB(A)]**
Cardboard enclosure	Varying thickness	E-1* E-2*	5-7 8-9
	Varying size	E-2* E-4*	7-9 10-12
Thermocole enclosure	Varying thickness	E-5* E-6*	9-10 11-13
	Varying Size	E-6* E-8*	12-13 13-15
Sandwich enclosure	Varying thickness	E-9* E-10*	11-13 19-20
	Varying size	E-10* E-12*	18-19 19-21
Air gap between cardboard enclosure walls Air gap between thermocole enclosure walls	2.5 cm air gap 5 cm air gap 2.5 cm air gap 5 cm air gap		15-17 18-19 18-20 21-23
Air gap between sandwich enclosure walls	2.5 cm air gap 5 cm air gap		24-25 27-28

* as detailed in Table 3

Near Field Noise Level Measurements

Near-field noise level measurements (equivalent noise levels) were made at 1 m distance from the generator (machine) operation. The same anti vibration mounts and enclosures used for indoor noise measurements were used here.

The near-field equivalent noise levels due to the generator operation, under idling and 90% load (460W) conditions, were 78.5 and 81.3 dB(A), respectively. The reduction in noise levels observed due to the control measures were not exactly similar to those observed in the indoor noise level measurements, probably due to structure-borne transmission. When the reduced noise levels (due to control measures) were compared with the 50 dB(A) daytime ambient noise standard (CPCB 2000), the results were not very encouraging. When a 5 cm air gap was used between sandwich enclosure walls, the resulting near-field noise level was 48.3 dB(A) during operation of the generator under idling condition; under 90% load (460W), the noise level was 52 dB(A).

The results obtained for the effect of anti-vibration mounts, enclosure types and air gaps between enclosure walls on near-field noise levels are detailed in Table 7, Table 8 and Table 9, respectively.

Table 7: Effect of Anti-Vibration Mounts on Near-Field Noise Levels

Measurement conditions		**Equivalent noise levels (L_{eq}) [dB(A)]**	
		Loading conditions of generator	
		Idling	**460 W load**
Without control measure		77.5	81.3
Thermocole pad (61cm x 38 cm)	t# = 16.34 mm t#= 32.68 mm	75.2 73.5	79.2 77.4
Polyurethane foam pad (61cm x 38 cm)	t# = 16.22 mm t# = 32.44 mm	74.2 72.4	78.4 76.5
Rubber pad (61cm x 38cm)	t# =16.14 mm t# = 32.28 mm	73.6 71.3	77.5 75.0
Wool-Felt pad (61cm x 38 cm)	t# =16.42 mm t#= 32.84 mm	73.4 71.1	77.6 75.5
Coir pad (61cm x 38cm)	t#= 16.32 mm t# = 32.64 mm	71.0 69.2	75.5 73.4
Sand bed (61cm x 38 cm) (Particle size=0.15mm)	t# = 16 mm t# = 32 mm	71.4 69.1	75.1 73.5
Sand bed (61cm x 38 cm) (Particle size=0.5 mm)	t# = 16 mm t# = 32 mm	69.4 67.3	73.3 71.6

Daytime ambient noise standard for silence zone L_{eq}: **50 dB(A)** [2]
t = thickness in mm

Table 8: Effect of Enclosures on Near-Field Noise Levels

Measurement conditions			Equivalent noise levels (L_{eq}) [dB(A)]	
			Loading conditions of generator	
			Idling	460 W load
Without control measure			77.5	81.3
Cardboard enclosure	Varying thickness	E-1* E-2*	70.0 68.2	74.2 72.1
	Varying size	E-2* E-4*	68.2 65.1	72.1 69.2
Thermocole enclosure	Varying thickness	E-5* E-6*	67.2 64.7	71.0 68.5
	Varying Size	E-6* E-8*	64.7 62.2	68.5 66.3
Sandwich enclosure	Varying thickness	E-9* E-10*	64.2 58.2	68.4 62.3
	Varying size	E-10* E-12*	58.2 56.6	62.3 60.5

Daytime ambient noise standard for silence zone L_{eq}: **50 dB(A)** [2]
* As detailed in table 3

Table 9: Effect of Air Gap between Enclosure Walls on Near-Field Noise Levels

Measurement Conditions		Equivalent Noise Levels (L_{eq}) [dB(A)]	
		Loading Conditions of Generator	
		Idling	460 W Load
Without control measure		77.5	81.3
Air gap between cardboard enclosure walls	2.5 cm air gap 5 cm air gap	60.5 58.6	64.5 62.0
Air gap between thermocole enclosure walls	2.5 cm air gap 5 cm air gap	57.4 54.6	61.5 58.4
Air gap between sandwich enclosure walls	2.5 cm air gap 5 cm air gap	51.9 **48.3**	55.8 52.0

Daytime ambient noise standard for silence zone L_{eq}: **50 dB(A)** [2]

COSTS OF NOISE CONTROL MEASURES

The costs (in Indian rupees) involved for the various noise control measures is detailed in Table 10.

Table 10: Costs of Materials used for Noise Control

Noise Control Measures		Cost (Rs.)	Basis for cost (market prices)
Thermocole pad	$t^{\#}$ = 16.34 mm	25	Rs.25 per sheet (100 cm x 50 cm)
Polyurethane foam pad	$t^{\#}$ = 16.22 mm	30	Rs.130 per sq. m
Rubber pad	$t^{\#}$ =16.14 mm	100	Market price
Wool-Felt pad	$t^{\#}$ =16.42 mm	105	Rs.160 per kg
Coir pad	$t^{\#}$= 16.32 mm	50	Market price
Cardboard Enclosure	E-1*	12	Market price
	E-2*	20	
	E-3*	25	
	E-4*	30	
Thermocole Enclosure	E-5*	50	Rs.16 per sheet (100 cm x 50 cm) of thermocole 10 mm thick
	E-7*	75	
	E-6*	75	Rs.25 per sheet (100 cm x 50 cm) of thermocole 16 mm thick
	E-8*	125	
Sandwich Enclosure	E-9*	70	Rs.20 for E-2*; Rs.16 per sheet (100 cm x 50 cm) of thermocole 10 mm thick
	E-10*	95	Rs.20 for E-2*; Rs.30 for E-4*; Rs.25 per sheet (100 cm x 50 cm) of thermocole 16 mm thick
	E-11*	100	
	E-12*	150	

thickness of pad in mm
* As detailed in Table 3

CONCLUSION

Among the anti-vibration mounts used in the study, the maximum reduction was due to the sand bed of thickness 32 mm (particle size 0.5 mm) which reduced noise by 10 dB(A). However, despite such reduction, the indoor noise levels and near-field noise levels did not conform to IS: 4954 (1968) [9] and CPCB [2], respectively.

Among the enclosure types, an air gap of 5 cm between sandwich enclosure walls was found to be most effective in controlling noise due to the generator operation with a reduction of 28 dB(A). On provision of the air gap of 5 cm between the sandwich enclosure walls, the indoor noise levels in the library, all the classrooms and entrance I of auditorium conformed to the noise level ranges specified in IS: 4954 (1968) [9]. An air gap of 2.5 cm between walls of the enclosures resulted in the indoor noise levels in classroom I conforming to the noise level range of 35-40 dB(A) specified for classrooms [9]. Near-field noise level of 48.3 dB(A) was observed, when a 5 cm air gap was used between walls of the sandwich enclosure, while the generator was operated under idling condition. However, despite such reduction, in certain other locations, the indoor noise levels and near-field noise levels did not conform to IS: 4954 (1968) [9] and CPCB [2], respectively. Hence, it may be concluded that more studies in noise reduction must be conducted, in order to prevent the detrimental health effects of noise on living organisms.

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