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# Experimental Investigations on Noise Reduction in Aden Cement Enterprise

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**Abstract**

In the last few decades, environment pollution problems created by noise in the industrial sites and community have become of great importance in the industrial countries because of their negative effects on the human-being health. Noise has many serious effects on workers health and causes also a number of serious diseases. Noise has therefore an environmental aspect and its levels have to be reduced near workers or peoples. In this paper, noise radiated by the generator room in Aden Cement Enterprise was measured and analysed. The noise levels measured were high compared to ISO standards. Therefore, a suitable proposal was recommended to reduce noise levels at the surrounding area using barrier materials for the generator room walls and roof and other suitable sound absorption materials from inside. Results of the new design can be adopted to limit the noise effects on workers' health.

**Keywords:** Noise, Noise Effects, Industrial Noise, Noise Measurement, Noise Control, Barriers, Acoustical Materials

**الملخص**

في العقود القليلة الماضية، أكتسبت مشاكل التلوث البيئي الناجم من خلال الضجيج في المواقع الصناعية و التجمّعات السكانية اهتمام كبير من قبل الدول الصناعية بسبب تأثيراتها السلبية علي صحة الإنسان. للضجيج أثار خطيرة على صحة العمال و يسبب أيضا" العديد من الأمراض الخطيرة. و لهذا السبب فأن الضجيج ذو بعد بيئي و يجب خفض مستواه بالقرب من العمال و الناس. في هذا البحث تم قياس و تحليل الضجيج المنتشر من غرفة المولدات الموجودة في شركة أسمنت عدن. مستويات الضجيج التي تم قياسها كانت عالية مقارنة بمعايير الأيزو. و لهذا تمت التوصية بمقترح مناسب لخفض مستويات الضجيج في المساحة المجاورة لغرفة المولدات بأستخدام مواد عزل مناسبة لجدران غرفة المولدات و السقف و مواد أخرى مناسبة لأمتصاص الصوت من الداخل. نتائج التصميم الجديد يمكن تطبيقها للحد من تأثيرات الضجيج على صحة العمال.

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## 1. INTRODUCTION

Sound can have a range of different physical characteristics, but it only becomes noise when it has an undesirable physiological or psychological effect on people [Berglund et. al., 1995]. Nevertheless, it is important to understand the physical characteristics of sound since these characteristics determine the various ways we have of measuring and describing sound. The main physical characteristics are: sound pressure level, sound frequency, type of sound, and variation in time. Typical sound pressure levels range from about 20 dB $L_{eq}$ in a very quiet rural area to between 50 and 70 dB $L_{eq}$ in towns during the day time, to 90 dB $L_{eq}$ or more in noisy factories to well over 120 dB $L_{A\max}$ near to a jet-aircraft at take-off.

Mechanised industry creates serious noise problems, subjecting a significant fraction of the working population to potentially harmful sound pressure levels of noise. It is responsible for high noise emissions indoor as well as outdoor of plants. In industrialised countries it has been estimated that noise levels of 75-85 dBA affect 15-20 % or more of the working population.

In industrial areas, the noise usually stems from a wide variety of sources, many of which are of complex nature. Various types of machinery are involved and they represent artificial noises that are of concern because they may contain predominantly low or high frequencies as well as tonal components. They may be impulsive and also present unpleasant and disruptive temporal sound patterns.

The difficulty of reducing the sound output and the noisiness of existing equipment is a serious obstacle to the improvement of working environments. To reduce the sound output from such sources, either the use of quieter plant and equipment is encouraged, or through zoning to separate industrial land uses from the more noise-sensitive residential areas or using measures for noise control [Richard H. Lyon, 1987]. When it is not economically possible to reduce the factory noise, the working hours of the workers have to be considerably reduced. Various methods of noise measurement and control in buildings and industry are presented in ref. [Bruel & Kjaer, 1988].

This paper presents the results of the work carried out in Aden Cement Enterprise. The area surrounding the generator room of size 20x26 m² was completely acoustically investigated and measured and noise mapping at three different times of the day were carried out on this area. Besides, sound pressure levels were measured at 5 critical locations around this area. The noise measurements were carried out using standard equipment and procedure. The A-weighted sound pressure levels measured were higher than the recommended ISO standard values. The results of noise measurements and analysis were used as basis for proposing a solution for attenuating the noise radiated to surroundings of the generator room.

## 2. PROBLEM DEFINITION

### 2.1 Noise Sources:

The generator room consists of approximately three identical generator sets, which can be described as three point sources**.** Specifications are given in Appendix I. In the free field, sound propagates outward from the point sources in uniform concentric circles.

Free field conditions exist when no obstacles block the sound path. Noise from a source can either be air borne or structure borne. Noise that travels through the air and through building walls and openings is called air-borne noise. Structure-borne noise is a term used to describe mechanical vibrations carried from machinery through to a building's structure. In this case the walls of the generator room are made up of hollow concrete block and therefore the air-borne noise phenomenon takes place and this air-borne noise must be measured and attenuated. Since this room is connected to other buildings of the factory, then the structure-borne noise has no influence in our subsequent analysis.

**2.2 Generator Room:**

The present generator room is acoustically not suitable to control the radiated noise, which is emitted by the three generators to the surrounding area of the factory. The walls are made up of hollow concrete blocks and galvanized steel sheets roof as shown in Fig. 1. The hollow concrete blocks help noise radiation to the surrounding area.

Fig. 1.: Present generator room, Aden Cement Enterprise

3. NOISE CONTROL METHODS

**3.1 Methods of Noise Attenuations:**

There are several methods available for controlling of noises emitted by machines in the industry. Internal noise level may be reduced by providing acoustical materials on walls, ceiling, etc [Siraskar, 1972]. But the noise generated inside the building is transmitted through air and through its structural links to the external area. The prevention of noise is thus mainly a problem of noise attenuation or noise reduction during its transmission through the barrier of the building. Acoustical materials do not help in this regard because their main function is to minimize noise reflection and not transmission.

The total absorption provided by an acoustical material of surface area $A$ m² and sound absorption coefficient $\alpha$ is obtained in Sabins [Siraskar, 1972] as

$$s = \alpha . A \text{, Sabins or m}^2 \quad (1)$$

In a hall the total sound absorption by different acoustical materials is given by the expression

$$S = s_1 + s_2 + s_3 + ... \\ = \alpha_1 A_1 + \alpha_2 A_2 + \alpha_3 A_3 + ... \qquad (2)$$

The values of $\alpha$ depend upon the nature of the material as well as the frequency of the sound. Therefore the values of $\alpha$ for a material are determined for a wide range of frequencies. The average value of $\alpha$ for certain frequencies is known as noise reduction coefficient $NRC$ of the material.

Barrier materials are dense and rigid and are defined in terms of their transmission loss $TL$ [ATCO Noise Management]. The higher the $TL$, the better a barrier material is at limiting or attenuating the amount of sound traveling through it.

Typically acoustic enclosures are modular boxes with relatively high transmission loss and absorptive internal surfaces place over the noise sources [ATCO Noise Management]. By virtue of design enclosures can create heat build up. Heat build-up is handled by adding a ventilation blower with silencers for intake and exhaust air. Designing total enclosures for the three machines inside the present room will not be a flexible solution for maintenance. Besides the volume of the present room is not large enough to accommodate all these arrangements.

Transmission loss $TL$ is defined as the logarithmic ratio of the sound power on one side of a barrier (wall or partition) to the sound power transmitted to the other side [ATCO Noise Management] as shown in Fig. 2. $TL$ is calculated as

$$TL = 10\log_{10}\frac{1}{\tau_c} = 10\log_{10}(W_i/W_t) \quad \text{dB} \qquad (3)$$

where
$\tau_c$ = sound transmission coefficient, ratio of the sound power level $PWL$ incident on one side to the $PWL$ on the other side
$W_i$ = incident sound power ($PWL$ on source side)
$W_t$ = transmitted sound power ($PWL$ on the receiver side)

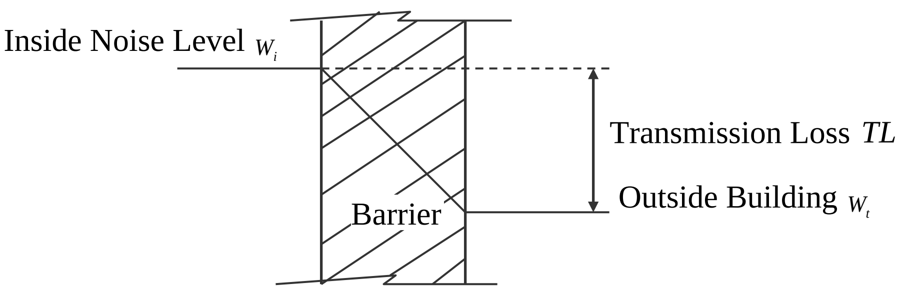


Fig. 2.: Transmission loss $TL$ of a barrier

If $A_1, A_2, A_3, ...$ etc. are areas of different partitions with $\tau_{c1}, \tau_{c2}, \tau_{c3}, ...$ etc. as their transmission coefficients, the total transmission $T$ of the room can be written as:

$$T = A_1\tau_{c1} + A_2\tau_{c2} + A_3\tau_{c3}, \ ... \qquad (4)$$

and the average transmission coefficient as:

$$\tau_{c(average)} = \frac{T}{A}, \tag{5}$$

where $A = A_1 + A_2 + A_3 + \ldots\ldots$ etc.

When the total sound absorption $S$ units and the total transmittance are determined for a room, its resultant total noise insulation can be estimated as a noise insulation factor, which can be written as

$$N_f = 10\log_{10}\frac{S}{T}\ \text{dB} \tag{6}$$

$TL$ values for some types of barrier walls and partitions are listed in Table 1 Appendix II.

### 3.2 ISO Standard Noise Criteria:

The ISO recommendation "Assessment of Noise with Respect to Community Response" [Hasall et. al., 1979], which will be used as an example of a typical procedure, suggests that a basic outdoor noise criterion of 35 to 45 dB (A) be applied in residential areas where measurements of the existing background noise levels are not available. Corrections recommended for different types of district are shown in Table 2, Appendix II.

Further corrections, which concern the time of the day, are shown in Table 3 appendix II. In addition, the criterion should not be set below 20 dB(A). For noise in non-residential rooms the following internal criteria are proposed, Table 4, Appendix II

## 4. DATA MEASUREMENT AND ANALYSIS

In this work, it was required to investigate and measure the A-weighted sound pressure levels $SPL$ and noise contour levels around the area surrounding the generator room of Aden Cement Enterprise and to prepare a noise mapping showing the area of the enterprise mostly affected by high noise levels. Besides, noise levels at generator room door, two check points and one office were measured as shown in Fig. 3.

In general, the area around the generator room were divided into a suitable net of 2x2 $m^2$ grid size and extended into a total area of 26x20 m. Measurement points were identified clearly using yellow colour. Measurement points located on the generator room were not measured. All other Measurement points (154 points) were considered and these measurements executed in two weeks; morning, mid-day and evening times. Five measurements were taken for every time; total no. of measurements = 154 x 3 x 5= 2310 points. This means 770 were taken in the morning time, 770 in the midday time and the other 770 points in the evening time.

### 4.1 Measurement Standard:

Standard procedure and equipment were considered for measurement of the sound pressure levels [Bruel & Kjaer primer, 1984]. For the purpose of evaluating conformance with the standards, noise levels shall be measured as follows:

1. Use of Meter. Any noise measurement shall be made with a sound level meter using the A-weighted network (scale). Calibration of the measurement equipment utilizing an acoustical calibrator shall be performed immediately prior to recording any noise data.
2. Measuring Exterior Noise Levels. Exterior noise levels shall be measured at the affected noise-sensitive area around the generator room. Where practical, the microphone shall be positioned 1.5 m above the ground and away from reflective surfaces.

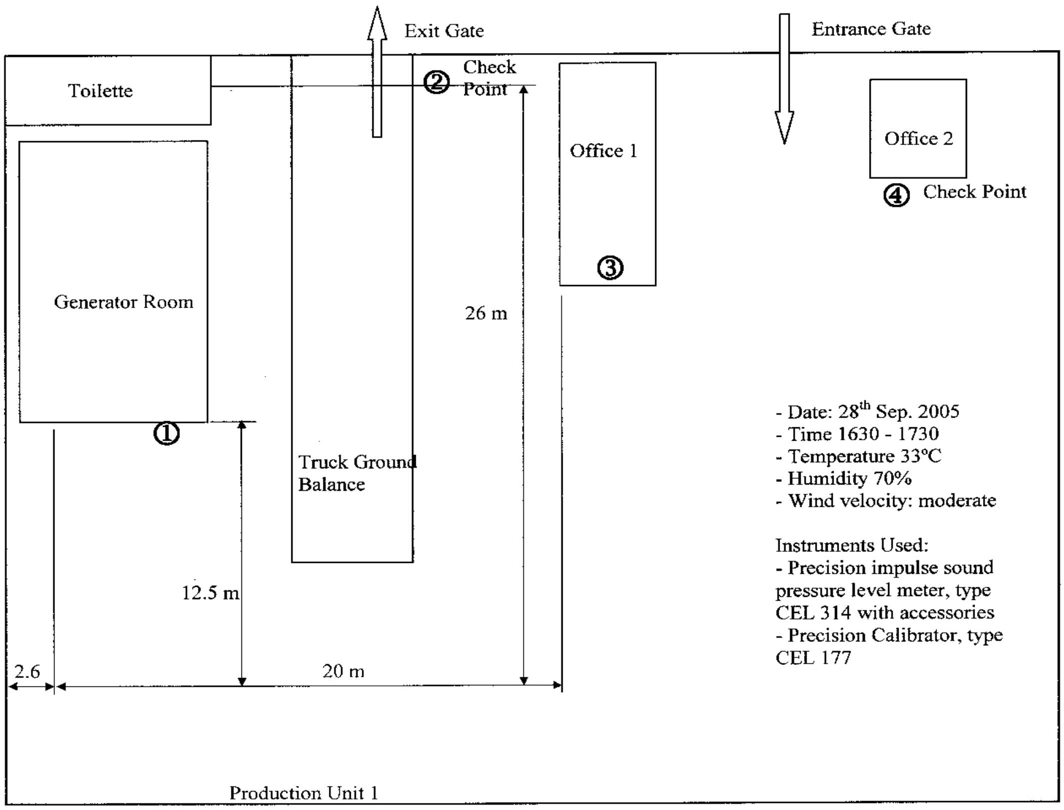


Fig. 3.: Area investigated around the generator room, Aden Cement Enterprise

All these generators are not in operation simultaneously. Each generator operates under a maximum load of about 150 kW. Once the electrical requirements exceed this load, the other generator is connected automatically into the electrical net of the enterprise to share the extra electrical load.

Other noise sources are like traffic noise of vehicles driven out side the premises, trucks moving around the factory, people working around, cars entering or leaving the factory. But their contribution to the total noise level is small and can be ignored.

Background noise were measured at location 1 in absence of noise coming from the above three generators and it has been found that this level lies around 70 dBA. Since the background noise is mainly small, then its effect on the total noise levels around the generator room can be cancelled.

### 4.2 Measurements Results:

The measurement results are illustrated in three noise mapping diagrams with contour plots. All the plots were prepared suing the software SIGAMPLOT 2000 for Windows Version 6.00. These A-weighted sound pressure levels were also measured at four critical locations as shown in Table 4, Appendix II. Labours, technicians, clerks and others visiting the enterprise always move around the investigated area and occupy these four locations. The workers sitting in the two check points are mostly influenced by these noise levels. The measurements were carried out in two weeks time and they represent the average of five readings.

**4.2.1 Sound Pressure Levels at Critical Locations:** There are in general four critical locations, which are engaged by workers and visitors in the investigated area as shown in Fig. 3. The average A-weighted sound pressure levels measured at these locations in two weeks time and three times a day are listed in Table 1.

Table 1: Average A-weighted sound pressure levels

| Locations, see Fig. 3 | Averaged A-weighted Sound Pressure Levels dBA | | |
|---|---|---|---|
| | Morning, 06:00 to 08:00 | Mid-day, 11:00 to 13:00 | Evening, 17:00 to 18:00 |
| 1 | 99.8 | 97.6 | 100.4 |
| 2 | 93.2 | 91.4 | 93.0 |
| 3 | 73.8 | 71.8 | 73.8 |
| 4 | 77.6 | 76.0 | 79.0 |

**4.2.2 Noise Mapping:** The noise mapping or noise contour levels may vary with temperature, pressure, wind velocity and any obstruction. As the wind velocity increases, the noise contours may expand to cover larger area. The area surrounding the generator room 20x26 m², see Fig. 3, was completely investigated. The A-weighted sound pressure levels were measured at all the measurement points. The average values are plotted all over the investigated area as shown in Fig. 4, 5 and 6 respectively.

### 4.3 Discussion of Results:

Referring to the sound pressure level measurements *SPL* shown in Table 1 and Figs. 4, 5 and 6 respectively and their amplitudes, we conclude the followings:

1. The complete area under critical situations, where noise levels varies from 84 to 105 dBA. Workers moving or working within this area are exposed to high noise levels.
2. All the noise contour diagrams show that the distribution of the noise levels at different day times are mainly similar in nature. The slight differences in amplitudes are due to temperature, wind velocity changes, obstructions and traffics.
3. The workers should not be exposed to these noise levels. Temporary solutions like wearing of ear protections or plugs may be useful. But this is a temporary solution and measures should be carried out to attenuate the noise levels to the standard acceptable limits.
4. The noise level in office 1 is also high, about 71.3 to 73.8 dBA, which can be roughly accepted. Normally it should be around 55 dBA. See ISO Tables 2 and 4 for outdoor and indoor noise criteria, Appendix II.

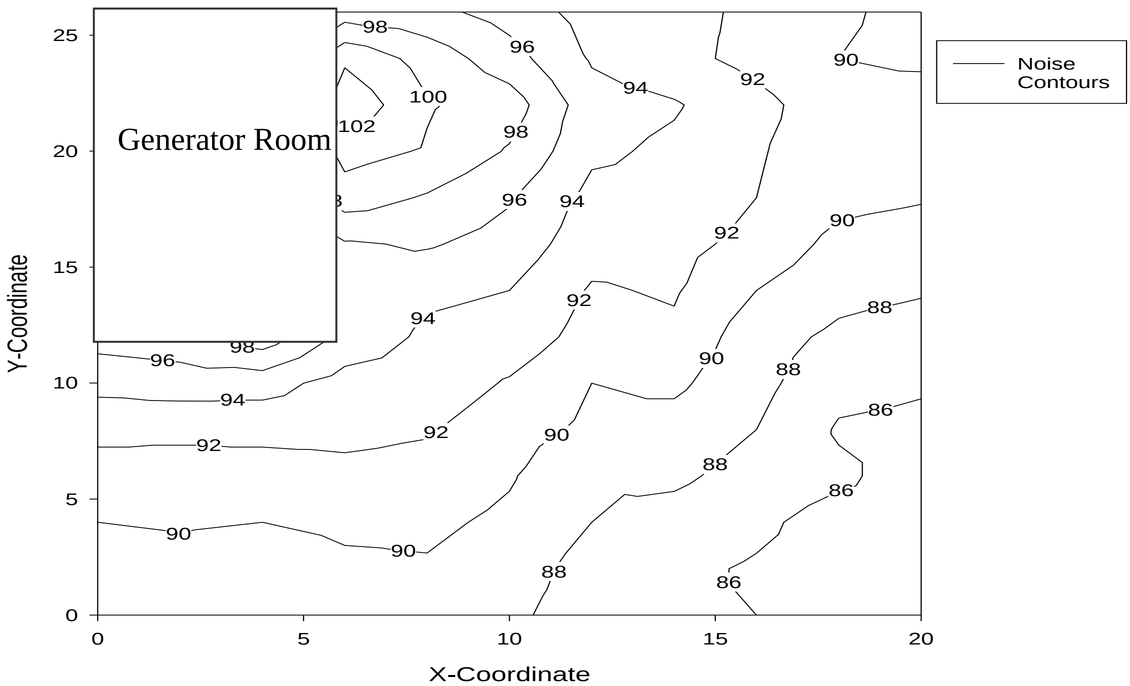


Fig. 4 Noise mapping contours during morning time, 06:00 to 08:00

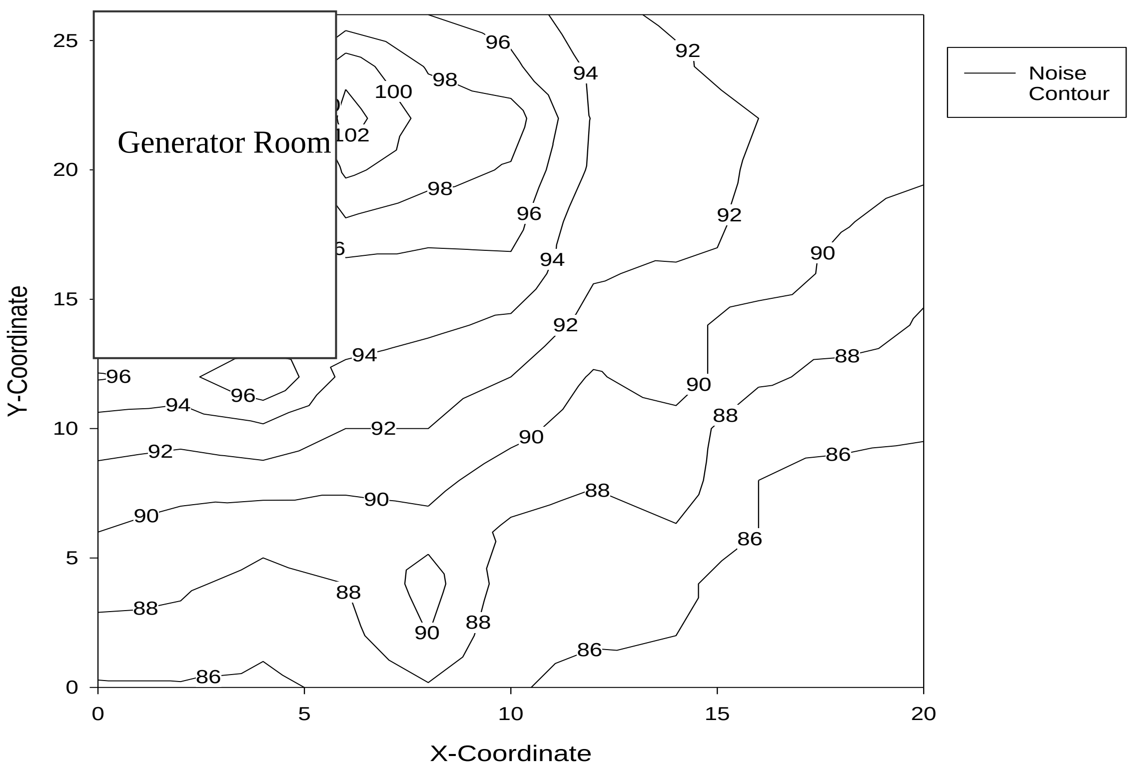


Fig.5.: Noise mapping contours during midday, 11:00 to 13:00

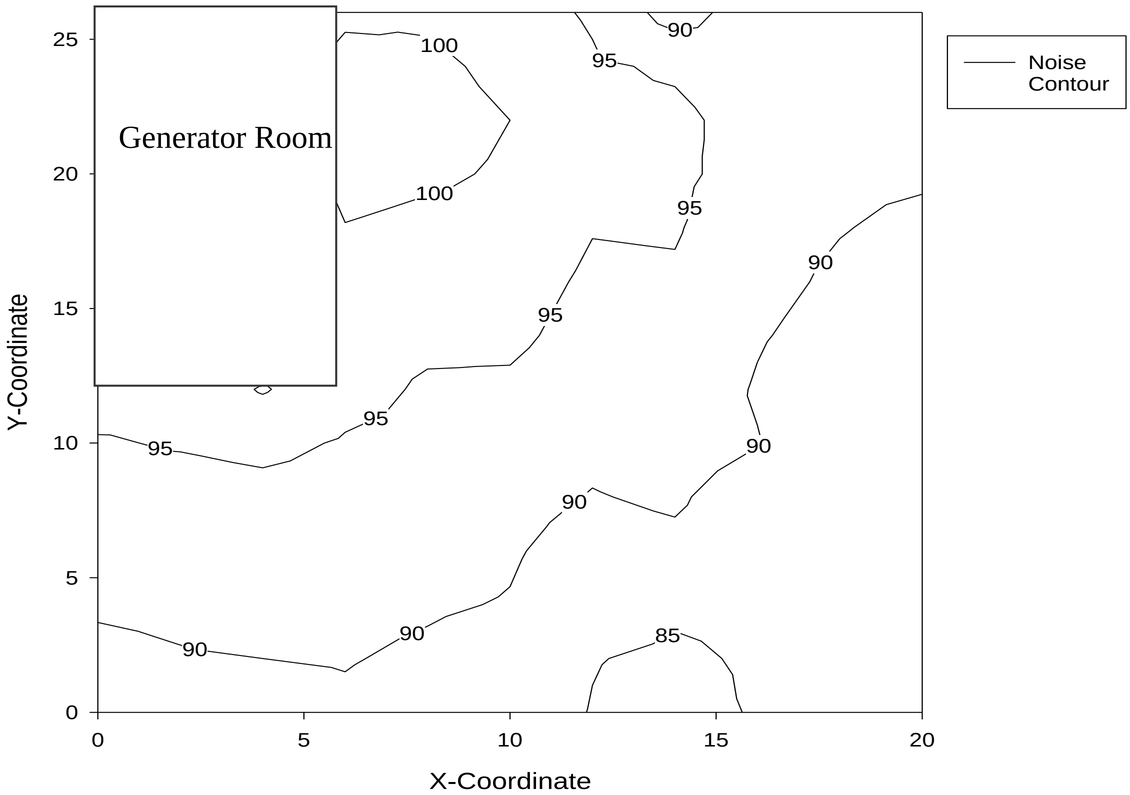


Fig. 6.: Noise mapping contours during evening time, 17:00 to 18:00

The guard man sitting in checkroom 1, exit gate, is mostly affected by high noise levels, from 97.6 to 100.4 dBA. This situation necessitates urgent measures for noise reduction or he should be moved from this place or his working hours must be reduced as per ISO standards. A criterion of 80 dBA for an eight-hours daily exposure would constitute a negligible hearing damage risk for speech. For every 3dBA increment in noise level, the working hours should be halved. Noise effects on human being are given in details in [EPA, 1979; Bies and et. al.; 1997].

5. The person sitting in checkpoint 2 is also exposed to noise levels of 76 to 79 dBA, which can be accepted for eight-hours daily exposure. See the same above references [EPA, 1979, Bies et. al., 1979].

6. The ideal solution is to shift the generator room to another place, where no workers or visitors are available. Since the factory management does not prefer to apply this solution, one recommends redesigning of the walls and roof of the present generator room to attenuate the noise levels to the acceptable levels.

## 5. PROPOSAL FOR EFFECTIVE NOISE CONTROL

The redesign of the walls and roof of the generator room necessitates the consideration of the following acoustical factors:

1. Using suitable barriers or walls with high transmission loss to attenuate the noise levels in the surrounding area.
2. Using suitable acoustical materials for roof and internal surface of the walls for sound absorption

3. Provision of ventilation systems to maintain the generator at the required working temperature

**5.1 Barriers or Walls of the Proposed Room:**

- The external dimensions of the room are 11.7x7.4x2.5m³, which should be maintained as per the management instruction. The wall thickness is 20 cm. One recommends here to change the present hollow concrete block walls into suitable barrier materials. Therefore knowing the noise level of incident air-borne noise and the desired noise criteria at the surrounding area one can choose appropriate types of construction for walls, doors etc. From Table 1, since the maximum noise level in the generator room is 115 dBA and it is required to maintain, say, a noise criteria of maximum 80 dBA in the surrounding area of the generator room, where the workers and visitors are available. Then in this case the new walls of this room must have a transmission loss of 35-40 dBA. One replaces the present hollow concrete block walls with solid walls of 9 cm unplastered bricks.

From eqn.(3) the transmission loss $TL = 10\log_{10}\frac{1}{\tau_c}$ and the transmission coefficients $\tau_{c1}$, $\tau_{c2}$, $\tau_{c3}$ and $\tau_{c4}$ of the four walls and floor comprising the room can be worked out from eqn.(3). In case of walls, these coefficients are equal. The corresponding areas are:

$A_1 = 2.5x(7.4\text{-}0.18)–2.2x1.5=14.75m^2$,
$A_3 = 2.5x(7.4\text{-}0.18)=18.05m^2$ and
$A_2 = A_4 = 2.5x(11.7\text{-}0.18)=28.80\ m^2$.

For walls, $TL = 40 = 10\log_{10}\frac{1}{\tau_c}$, therefore the sound transmission coefficient for each wall is $\tau_{c1} = 1.0x10^{-4} = \tau_{c2} = \tau_{c3} = \tau_{c4}$.

- The floor of the room is cement-plastered and can be maintained as it is. Its approximate area is $A_5 = 83.17$ m². One recommends an average transmission loss for concrete reinforced floor as 45 dB, [Bies et. al., 1979].

For floors, $TL = 45 = 10\log_{10}\frac{1}{\tau_{c5}}$, therefore $\tau_{c5} = 3.16x10^{-5}$.

- There is only a simple hollow steel-bared door with dimensions as 1.5m wide and 2.2m high ($A_6 = 3.30$ m²). This door should be changed with a new one. A hardwood door with 54 mm thickness can provide an average transmission loss of 25 dB as suggested by Bies et. al., [1979].

For the door, $TL = 25 = 10\log_{10}\frac{1}{\tau_{c6}}$, therefore $\tau_{c6} = 3.16x10^{-3}$.

- The present room has corrugated galvanized steel sheets, 1mm thick, and simply fixed on four beams of the room. The roof has an area of $A_7 = 83.17$ m². These steel sheets can be replaced by 1.5 mm lead between two sheets of 5mm plywood. The average transmission loss factor for such a material is 35 dB [Bies et. al., 1979]

For the roof, $TL = 35 = 10\log_{10}\frac{1}{\tau_{c7}}$, therefore $\tau_{c7} = 3.16x10^{-4}$.

Therefore the total transmittance $T$ , from eqn.(4), is:

$$T = \tau_{c1}A_1 + \tau_{c2}A_2 + ... + \tau_{c7}A_7 = 0.0484 \text{ m}^2. \quad (7)$$

**5.2 Acoustical Materials on Internal Surfaces of Walls and Roof:**

The noise inside the generator room can be reduced using acoustical materials attached on the internal surfaces of walls and roofs. One can recommend that scrim mat fiberglass with rigid backing and 25 mm thickness is applied all over the internal surfaces of walls and roof [Siraskar, 1972]. Such a material has a noise reduction coefficient *NRC* of 0.79. The concrete floor has noise reduction coefficient of 0.04.

From eqn.(2), the total sound absorption of the room is sum of the sound absorptions of walls, floor and roof respectively and is given by

$$S = \alpha_1 A_1 + \alpha_2 A_2 + \alpha_3 A_3 + ...$$
$$= 0.79(A_1 + A_2 + A_3 + A_4 + A_6 + A_7) + 0.04A_5 = 139.676 \text{ m}^2. \quad (8)$$

Using results of eqns.(7) and (8) respectively, the noise insulation factor for the room, from eqn.(6), is

$$N_f = 10\log_{10}\frac{S}{T} = \frac{139.676}{0.0484} = 34.60 \text{ or say it is 35.0 dB.} \quad (9)$$

It may be seen that when the outside noise level is 80 dB the average inside noise level for the room under consideration will be 115 dB minus its insulation factor of 35 dB, i.e. 80 dB. However, the noise insulation factor worked out in this proposal is based on medium value of sound absorption coefficients. If the room is treated with acoustical materials with higher values of $\alpha$, then the noise insulation of the room will be greater. But it is generally uneconomical to obtain high values of $N_f$ by increasing $S$ alone. The value of transmittance $T$ must be lowered, i.e. the $TL$ ratings must be higher to obtain increased $N_f$ for a room. Thus for economical noise, proof construction high $TL$ ratings only of walls and floors are useless unless the $TL$ ratings of doors and windows are also comparably high.

**4.3 Provision of Ventilation System:**

The proposed room should be provided with ventilation system to maintain the room temperature at the desired level. Since no openings are provided, the heat generated because of the control panel and the generators will increase the inside temperature. To keep equipment from overheating, fans and internal ducting also are needed to supply cool air and remove hot air. The minimum flow rate of cooling air, $Q$ (in m$^3$/s), depends on the power $W$, the watts of heat generated, and $\Delta T$ temperature rise permitted. Cooling airflow rate is calculated [WWW.engineeringtoolbox.com] as

$$Q_c = H_c / \rho C_p \left(t_o - t_r\right), \tag{10}$$

where $Q_c$ = volume of air for cooling (m$^3$/s), $H_c$ =cooling load (W), $c_p$ = specific heat capacity of air (kJ/kg), $t_s$ = supply temperature (ºC), $t_r$ = room temperature (ºC), $\rho$ = density of air (kg/m$^3$)

Knowing the heat generated inside the generator room and the permissible temperature rise, a proper ventilation system can be designed. In this case two sections of the control panel and two generator sets are simultaneously in operation, see Appendix I for technical data. The switchgear of each section has low voltage breaker up to 400 Amperes and it radiates heat of 100 W [Bell, 2000]. Therefore, if two sections of the panel are simultaneously in operation, then their total radiated heat is 200 W. For generator sets, most of the heat is radiated by the diesel engine. The electric generator has a power of 200 kW or about 268 HP, Appendix I. Such equipment radiates heat of about 60 W/HP [Bell, 1988]. The total heat generated by any two electric generators working simultaneously is 2x268x60= 32,160.00 W.

From engine energy balance, the convection and radiation from engine's external surface is about 2-6% of the maximum input power [Heywood, 1988]. If we consider the maximum limit, then 6% of the heat generated in the engines is radiated to the surrounding. The input energy to the engine is calculated [Heywood, 1988] as

$$\text{Input energy } H = m_f Hs \text{, Watts} \tag{11}$$

Where $m_f$ =mass flow rate in kg/s, $Hs$ =Mean Kalorific Value of diesel in kJ/kg. Using the data, $H = m_f Hs$ = 0.00486 kg/s x 42000 kJ/kg= 204,120.0 W. For two engines operating at a time, the total heat radiated is 2x204,120.0x6% = 24,494.4 W.

Generally, mechanical equipment rooms only require ventilation. Most mechanical rooms are designed for 95ºF to 105ºF. If space temperatures below 90ºF are required by mechanical equipment, air conditioning of space will be required. If outside air is used to ventilate the mechanical room, the mechanical room design temperature will be 10ºF to 15ºF above outside summer design temperatures [Bell, 2000].

If outside summer design temperature is 40ºC and maximum inside mechanical room temperature is to be maintained at 45ºC, using eqn.(10), the minimum flow rate capacity of a fan may be calculated as

$Q_c = H_c / \rho C_p \left(t_o - t_r\right)$ = (200.0+32,160.0+24,494.4)/1.2x1000(40-45)= -5.68 m$^3$/s.

Two fans with capacities of 5.68 m$^3$/s should be provided in this room. One should be positioned at bottom of the east wall to introduce the cooling air and the other one can be fixed at the top of the opposite wall to discharge the hot air outside.

## 6. CONCLUSIONS AND RECOMMENDATIONS

- The results of noise measurements as illustrated by noise contours levels conclude that the surrounding area to the generator room is under high noise levels.
- The first measure or recommendation is to protect the guard man in checkpoint 2 and the workers and visitors moving around this area. This can be achieved using ear protection or reducing their working hours as requested by ISO standards. This measure should be understood as a temporary solution for the noise problem.
- A permanent solution for noise problem can be approached using noise attenuation techniques as described in section 5.
- The recommended proposal for redesigning of the generator room with new barrier walls and roof materials show the basic steps and requirements for noise attenuation outside the generator room and noise absorption inside the room.
- The selection of acoustical or barrier materials in the proposal is meant only for illustration purpose. Economical aspects; i.e. costs of redesign and construction plus costs of barrier and acoustical materials, and the noise criteria required to be maintained at the surrounding area shall decide which material have to be used for the new design.

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## Appendix I

Three power generators erected in the generator room with the following specifications:

| Specifications | Generator 1 | Generator 2 | Generator 3 |
|---|---|---|---|
| Power: | 250 kVA, 200 kW, | 250 kVA, 200 kW, | 250 kVA, 200 kW |
| Power factor: | 0.8 | 0.8 | 0.8 |
| Phase; | 3 | 3 | 3 |
| Hz: | 50 | 50 | 50 |
| Speed, rpm | 1500 | 1500 | 1500 |
| Generator: | 440 V, 361 A | 440 V, 361 A | 440 V, 361 A |
| Excitation: | 44 V, 8.3 A | 44 V, 8.3 A | 44 V, 8.3 A |
| Ambient temperature: | 40ºC | 40ºC | 40ºC |
| Manufacture: | Caterpillar, | Caterpillar | Caterpillar |
| Year of Production: | 1998 | 1995 | 2000 |
| Maximum working load | 150 kW | 150 kW | 150 kW |

The automatic synchronisation control panel consists of three sections, each with manual switchgear, to control all the three generators. Each generator works to a maximum load of 150 kW. Once the electrical requirements exceed this limit, then the second generator is connected automatically into the net to share the extra load. Therefore, there are simultaneously two sections of the control panel and two generator sets in operation.

**Appendix II, T**able 1: Values of *TL* for various types of construction of walls and partitions (Adapted from the British Standard Code of Practice 1960) [Siraskar 1972]

| No. | Construction | *TL* in dB (Average for 100-3200 Hz) |
|---|---|---|
| | **Solid Walls** | |
| 1. | 9 cm brick, unplastered | 35 – 40 |
| 2. | 20 cm brick with 12.5 mm plaster on both sides | 50 |
| 3. | 30 cm brick with 12.5 mm plaster on both sides | 53 |
| 4. | 40 cm brick with 12.5 mm plaster on both sides | 55 |
| | **Double Leaf Walls (with thin wire ties)** | |
| 5. | 5 cm woodwool leaves with 5 cm cavity and 12.5 mm plaster on both sides | 42 |
| 6. | 5 cm clinker block leaves with 15 cm cavity and 12.5 mm plaster on both sides | 50 |
| 7. | 10 cm clinker block leaves with 5 cm cavity and 12.5 mm plaster on both sides | 50 |
| 8. | 10 cm. brick leaves with 5 cm cavity and 12.5 mm plaster both sides | 50 - 53 |
| | **Single Leaf Partition** | |
| 9. | 25 mm glass wool or mineral wool | 5 |
| 10. | 12.5 mm fibre insulation board | 18 |
| 11. | 3 mm hard board | 20 |
| 12. | 6 mm plywood | 21 |
| 13. | 20 mm chipboard | 26 |
| | **Stud Framed Partition** | |
| 14. | 12.5 mm fibre board both sides | 20 - 22 |
| 15. | 8 mm hardboard both sides | 23 |
| 16. | 6 mm plywood both sides | 24 |
| 17. | 20 cm black board both sides | 30 |

Table 2: Noise criteria N.C. for outdoors

| Type of District | Correction to Basic criterion dB (A) | Final Noise Criteria N.C. |
|---|---|---|
| Rural residential, zones of hospitals, recreation | 0 | 35-45 |
| Suburban residential, little road traffic | +5 | 40-50 |
| Urban residential | +10 | 45-55 |
| Residential urban with some workshops or with business or with main roads | +15 | 50-60 |
| City (business, trade, administration) | +20 | 55-65 |
| Predominantly industrial area (heavy industry) | +25 | 60-70 |

Table 3: Correction factors for daytime

| Time of day | Correction to basic criterion, dB (A) |
|---|---|
| Day time | 0 |
| Evening | -5 |
| Night time | -10 to -15 |

Table 4: Internal noise criteria

| Type of Room | Noise Criterion, dB (A) |
|---|---|
| Larger office, business store, department store, Meeting room, quiet restaurant | 35 |
| Larger restaurant, secretarial office with type writer | 45 |
| Larger typing halls | 55 |
| Workshops | 45-75 |