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FREQUENCY-DEPENDENT NOISE CHARACTERISTICS IN A GAS-TO-LIQUID PLANT IN THE SWAMP AREA OF THE NIGER DELTA

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ABSTRACT

Noise spectra have been mapped out by the 1/3rd octave band analysis in a Gas-to-Liquid Plant in the swampy area of the Niger Delta using a Pulsar Model 33 Spectrum Analyser. The analyses with a CESVA Capture Studio Software were carried out in seven Zones. Results show that Zones 2 (Trains area), 3 (Process area) and 7 (Deluge equipment and Custody meter area) had peak mean Band Pressure Noise Level between 85.3 dB – 89.9 dB above the DPR limit, a level which is the starting point where damage risk to hearing is thought to be imminent and at the 2 - 4 kHz frequencies range where the normal human ear is more responsive. These Zones also had high levels of annoyance due to the heavy duty machines and plants and rotating parts of machinery in constant daily operation. Zones 5 (Pig launcher/Receiver and slug catcher area) and 6 (LPG storage area having Spherical tanks only) registered peak mean Band Pressure Noise Level of 83.5 dB and 86.6 dB respectively at the 20 Hz frequency band due to their proximity to the nearby Gas flare area. Such low frequency noises can be harmful to body resonance especially the head-neck shoulder system of employees Zones 1(Office and water utility area) and 4 (Hot oil area) registered noise levels less than 85 dB at low frequencies because of the absence of the machinery that generates high noise and their distances away from the Gas flare area. These suggest that the type of noise dominant within the Plant was discrete noise obscured by broadband noise. Impact noise may not have been experienced since there were no operations generating such type of noise.

KEYWORDS: Discrete and Broadband Noises, 1/3rd Octave Band Frequency, Pulsar Model 33 Spectrum Analyser, Gas-to-Liquid Plant, Niger Delta.

INTRODUCTION

Noise essentially is sound that is not desired by the recipient. A given sound constitutes an annoying noise depending on many factors such as pitch, irregularities, duration, loudness, rhythm, unexpectedness, frequency or whether the noise has a meaning to the particular observer. The sensitivity of the human ear to a particular noise depends on the frequency of the sound. Frequency determines the pitch of the sound. Doubling frequency produces an approximate increase of one octave. The frequencies that the normal human ear can detect (audio-frequency) range from about 20 Hz to 20 kHz. Below 20 Hz lies the range of infrasound and above 20 kHz lies the range of ultrasound. Sounds in the infrasonic and ultrasonic regions are rarely of interest in environmental noise studies.

Most industrial noise in an industrial or environmental context consist of many different frequencies, although equipment such as fans, turbines, transformers and the like can produce noise with discrete frequencies that may lead to audible tonal characteristics. Tonal noise is generally more noticeable and more annoying than non-tonal (Broadband) noise of the same level. Whilst tonality can be judged subjectively, it will be useful to measure it. This can be done through octave band, 1/3rd octave band or sometimes narrow-band analysis.

In Nigeria, few reports on the spectral characteristics of noise are available. However, Onuu and Menkiti (1992) have analysed the spectra of road traffic noise for parts of the South-Eastern Nigeria and concluded that this type of noise dominates the low frequency range (500 – 800 Hz). The spectral analysis of industrial noise in nine (9) industrial layouts in Calabar, Nigeria by Onuu et. al (1996) revealed octave band pressure levels well above 85 dB(A). The spectral distribution of the acoustic energy in these industries tended to be Gaussian and semi-(quasi)-Gaussian with levels between 1 and 4 kHz such that workers are exposed to serious possible hearing impairment as well as concomitant pathological danger. Akpan and Onuu (2004) measured sound pressure levels and produced noise spectra in selected industries in South-Eastern Nigeria. They obtained results which show octave band pressure levels which were Gaussian and well above 90 dB(A) with peak at about 2 kHz where the normal ear is very sensitive.

More noise frequency analysis of industrial plants and factories in Nigeria is necessary so that a noise spectrum can be mapped out. This will allow the determination of the general spectra of noise since certain low frequency waves are harmful to body resonance (Abumere et al, 1999). For example, the head-neck shoulder system has resonance effect in the 20 – 30 Hz region, eyeball resonance occur in the 60 – 90 Hz region whereas the lower jaw-skull resonance is found between 100 – 200 Hz (Menkiti, 1994) while certain high frequency noise can be a source of annoyance and discomfort.

Sequel to this, a noise survey was conducted in a Gas-to-Liquid Plant in the Niger Delta with a view to determining its spectral characteristics by the 1/3rd octave band analysis. The results of this study will enable us understand the frequency-characteristics of noise employees are exposed to.

STUDY AREA

The noise survey covers the area within the Gas-to-liquid Plant built on the west bank of the tidal outlet of Escravos River in the Niger Delta about 2 km north of its confluence with the Atlantic ocean on the Bight of Benin, approximately 160 km south-east of Lagos and about 60 km west of Warri, Nigeria. It occupies an areal portion approximately 2.5 km² (Figure 1). To the Plant true north, is a heavily forested swamp with no human habitation. This is also the case with the North-East and North-West of the study area. To the South is the Escravos terminal with heavy industrial activities such as construction, loading and offloading of barges at the dock area, heavy-duty vehicular movements, welding and fabrication activities, among others. The major source of noise interference around the study area is that from heavy-duty construction vehicles working around the Gas Plant.

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APPENDIX A

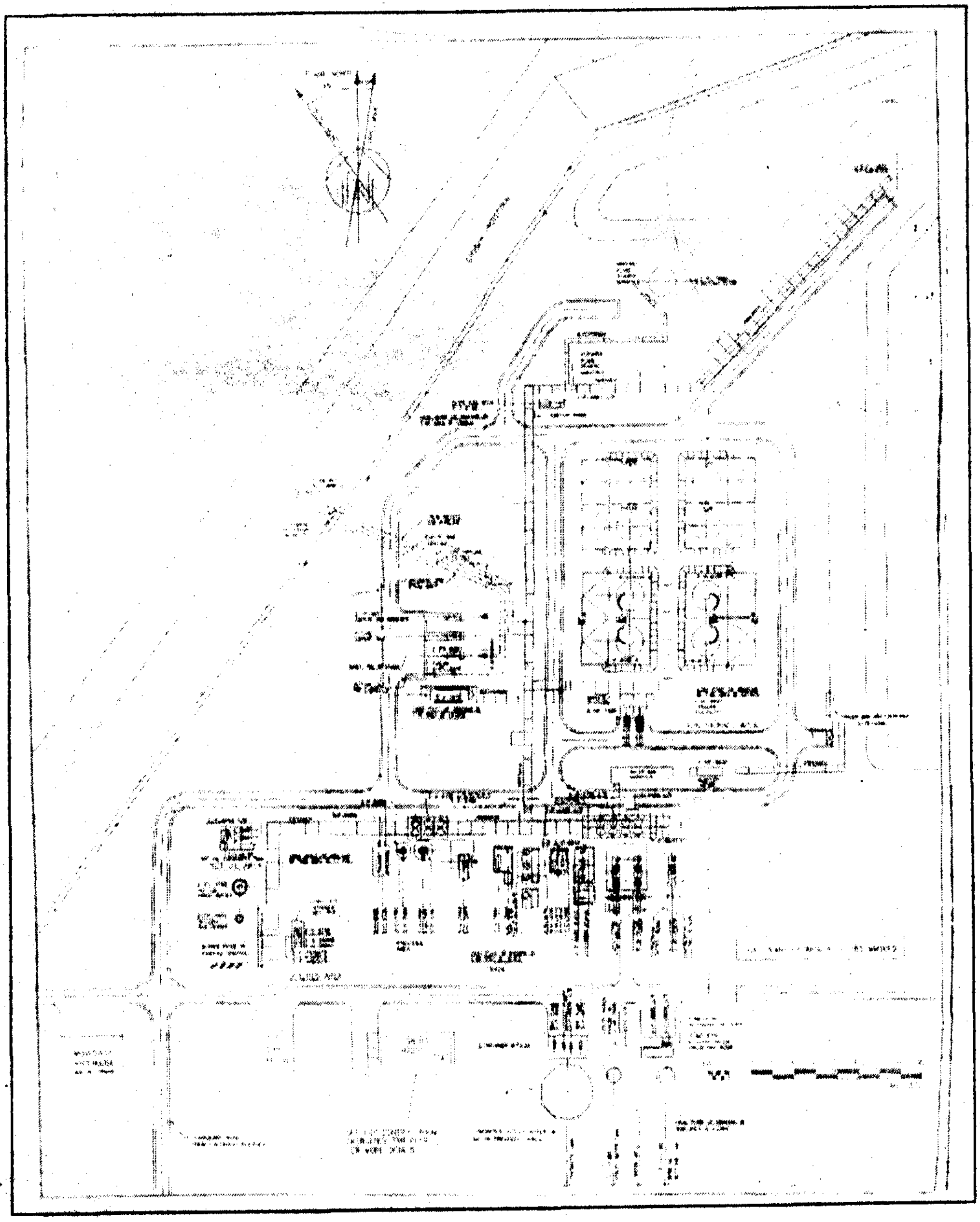

FIGURE 1: Map of the gas liquefaction area

TYPES AND SOURCES OF NOISE WITHIN A GAS-TO-LIQUID PLANT

In an industrial set-up such as the Gas-to-Liquid Plant in which the study was conducted, the major sources of noise can be identified and classified by their different spectral characteristics which possess unique acoustical signatures. These spectral characteristics of noise are divided into three basic and distinctly different types namely:

Discrete Frequency Noise

This is the most common type of noise found in an industrial setting. This type of noise is characterised by pure tones concentrated in a "narrow band" of the spectrum or contains a high proportion of the energy at a single frequency and is generated mainly from the rotating parts of machinery. These may include noise from:

- Fans, rotary positive displacement blowers
- Compressors, Pumps
- Internal combustion engines
- Gears, timing belts
- Transformers and so on.

The frequencies of this machinery are usually easy to predict. They are related to shaft rotational speed and the number of fan blades, gear teeth, vanes and so on.

Fan noise, a typical example of discrete frequency noise is a commonly occurring environmental noise problem which can produce tonal, whining or beating noises. Fan noise is primarily produced as a result of the turbulence produced by the fan blades and is a function of the number of blades and the fan-tip speed. The frequency generated by the passing blades of fans is known as the blade-pass frequency and is determined by (IPPC, 2004):

$$f = nr \qquad (1)$$

where f = the blade-pass frequency
r = fan speed (rpm)
n = the number of fan blades

The number of multiples (harmonics) of this frequency (2nr, 3nr, 4nr,....) may also be produced and can be seen across the noise spectrum. Additional peaks may be produced by obstructions to the airflow or blade spacing irregularities.

Discrete frequency noise can also result from the noise associated with the combustion processes. This is largely due to the unsteady burning of fuel and the gas velocity involved. Pumps or compressors used to pressurize hydraulic systems also produce this type of noise.

Broadband Noise

This is another common type of industrial noise. It is characterised as a rumble, roar or hiss. The major source of this type of noise is that associated with discharging high-velocity air. The broadband noise here originates from the aerodynamic shearing of the ambient air by the high-velocity jet. The shearing action creates swirling eddy-like turbulence with corresponding dynamic sound pressure fluctuations. The turbulence mixing is non-periodic in nature and as such the sound pressure produced is random in both amplitude and phase. Thus, there are no discrete frequency tones present. The acoustical signature is concentrated in one or more areas of the spectrum. An example is noise from a gas flare. The turbulent airflow is caused by the high-velocity, high-temperature gas flow. Noise levels increase with increasing gas velocity and temperature. At velocities below 30 m/s, noise generation is not usually a major concern. Noise caused by the turbulent airflow is generally low frequency (below 50 Hz). Consequently, flare noise can be more annoying at sensitive receptors than an 'A'-weighted level would suggest. It can therefore be meaningful to measure the noise using a linear scale as 'A'-weighting tends to under-represent the effects of the low frequencies. Combustion during gas flaring produces low-frequency noise, below 350 Hz. Noise from injection of smoke suppressant, such as high-pressure steam, produces high-frequency noise. Steam injection also improves combustion efficiency, thereby increasing the combustion roar. Noise levels produced by gas flares can vary widely and under some circumstances have produced sound power levels approaching 140 dB (linear). This equates to around 85 dB (linear) some 200 metres away.

Impact Noise

This refers to transient acoustical events of short duration usually less than 0.5 s. It involves a change in sound pressure level above some minimum reference value usually taken as 40 dB (Taylor, 1978). Impact noise can be divided into three types in terms of the means of productions:

- Impulsive action produced as part of the operation of a machine (for example, presses, drop hammers)
- Incidental to machine operation (for example, hoppers, vibrating conveyors, screens)
- Operating procedures (for example, dropping steel plates, timber).

This type of noise often comprises many frequencies and the solutions may range from operational ones (reducing drop heights) to mechanical ones (using resilient linings).

METHODOLOGY

The survey for this assessment was conducted using a Pulsar Model 33 Spectrum Analyser. This instrument is a type-1 integrating-average sound level meter that conforms to IEC 60651, IEC 60804, IEC 61672, EN 60651, EN 60804, IEC 61260, EN 61260, ANSI S1.4 and ANSI S1.43 International Standards. It is a powerful, user-friendly instrument for acoustic measurements. It measures in real time and in 1/3rd octave and octave bands with type 1 filter.

In the course of this survey, the instrument was calibrated at 94.0 dB before and after every measurement in accordance with the manufacturer's approved calibrator which also conformed to ANSI S1.10. It was set at 'slow' for A-weighted sound level measurements. An omni-directional microphone windscreen was used for all measurements to ensure that wind effects/turbulence is reduced minimally. The instrument was always held at a height of 1.5 m above the ground and 1.0 m from the source producing the noise in conformity with ANSI S1.13.

The area within the Plant was divided into seven zones and measurements were taken for a continuous period of 26 hours. This was to effectively cover the entire Plant and determine the noisiest sections of the Plant.

Each point was sampled for about two minutes. The instrument was programmed to run at an integration time of 1s. Two-minute intervals were allowed to move from one location to another, before setting-up and initialization. Measurements were taken when all neighbouring Plants were running with the noise meter microphone directed towards the nearest noise source in all cases.

Throughout the measurement period, the weather was fairly clement and the wind direction was South-West/West with a peak speed which stood at about 4.0 m/s with an average of 2.8 m/s. The entire sample points were georeferenced with a 12-channel Gamin Global Positioning System (GPS) except when under a roof cover.

DATA PROCESSING, ANALYSIS AND INTERPRETATION

All the Real Time noise measurements were automatically stored in the Pulsar Model 33 Spectrum Analyser and later downloaded into a Laptop computer. A software (CESVA Capture Studio) was utilized for processing and analysing the data. This CESVA Capture Studio automatically does the noise spectrum analyses and determines the 1/3rd octave band as required for this study. After processing, the CESVA Capture Studio software presents the data in various graphical forms for further interpretation. Figure 2 is a typical example of the analysed form of the 1/3rd octave band measurements.

The analysis is carried out in various modes such as the Numerical Analyser Mode (Figure 2) which shows the noise duration of 2 minutes, instrument integration time of 1 second, A-weighting network and the measured 1/3rd Octave band frequency noise values; the Frequency Graphic Analyser Mode which is histogram plot of the measured 1/3rd Octave band frequency values in Hz against the Noise levels in dB; the Graphic Time History Analyser Mode which shows the 1/3rd Octave band frequency noise values plotted against measurement time per second and the 3D Graphic Analyser Mode showing the noise data plotted in the Time and Frequency domain

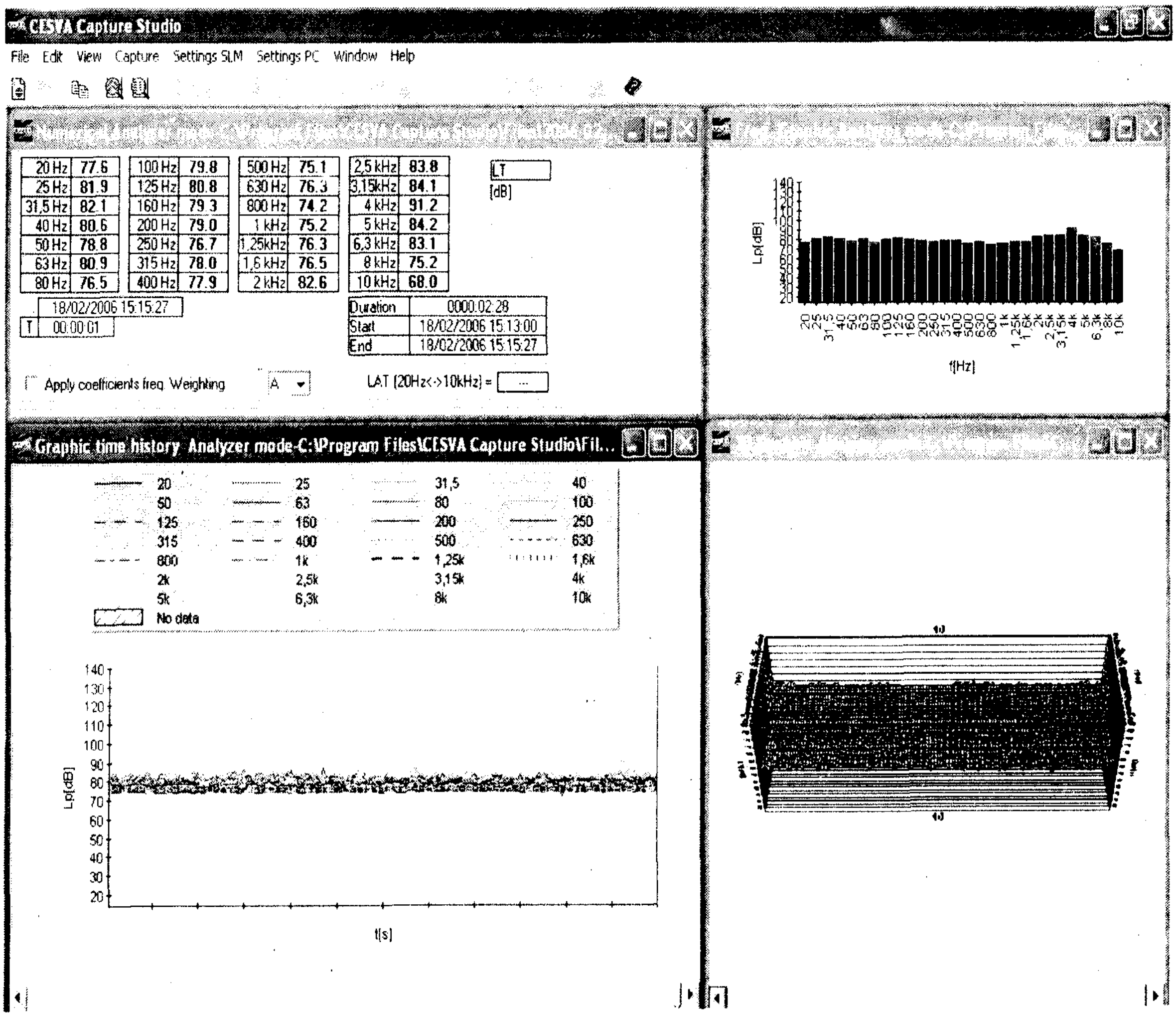

Fig. 2: Typical analysis in different modes for a sample point

RESULTS AND DISCUSSION

The results of the analysis of the 1/3rd Octave band frequency dependent noise levels for the various Zones are presented in Figures 3 - 9.

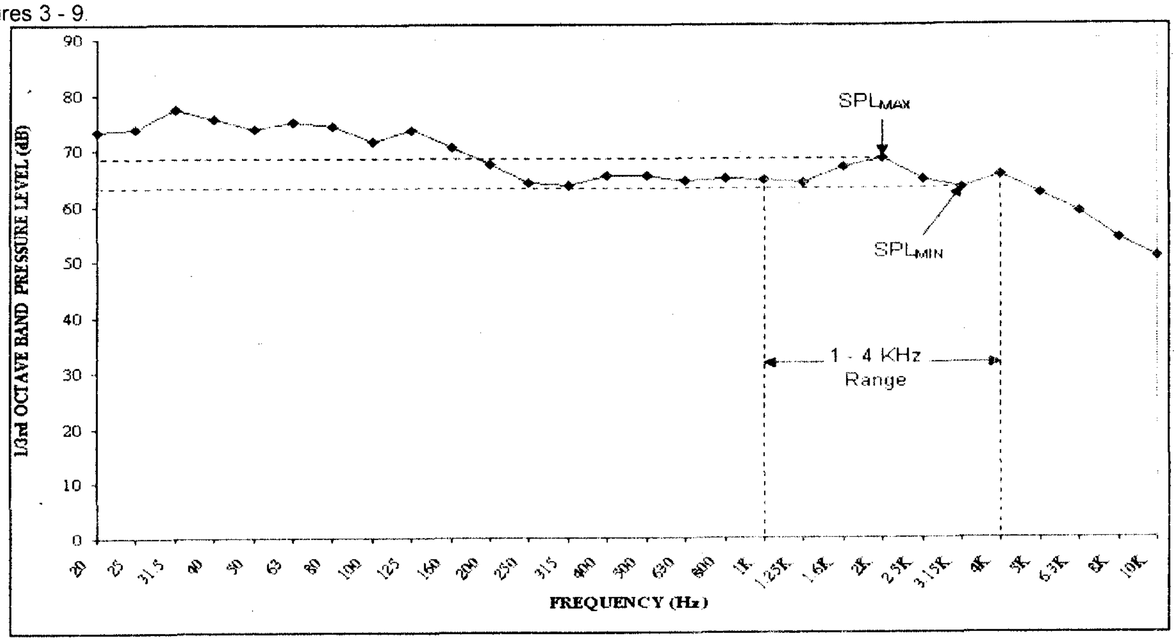

FIGURE 3: Noise Spectrum For Zone 1

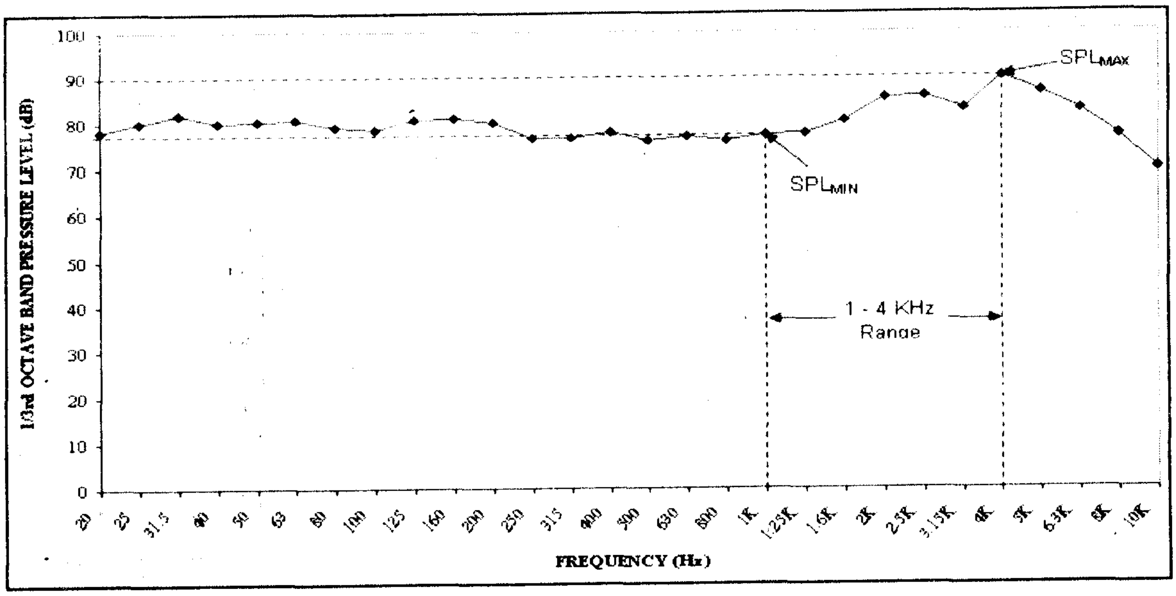

FIGURE 4: Noise Spectrum For Zone 2

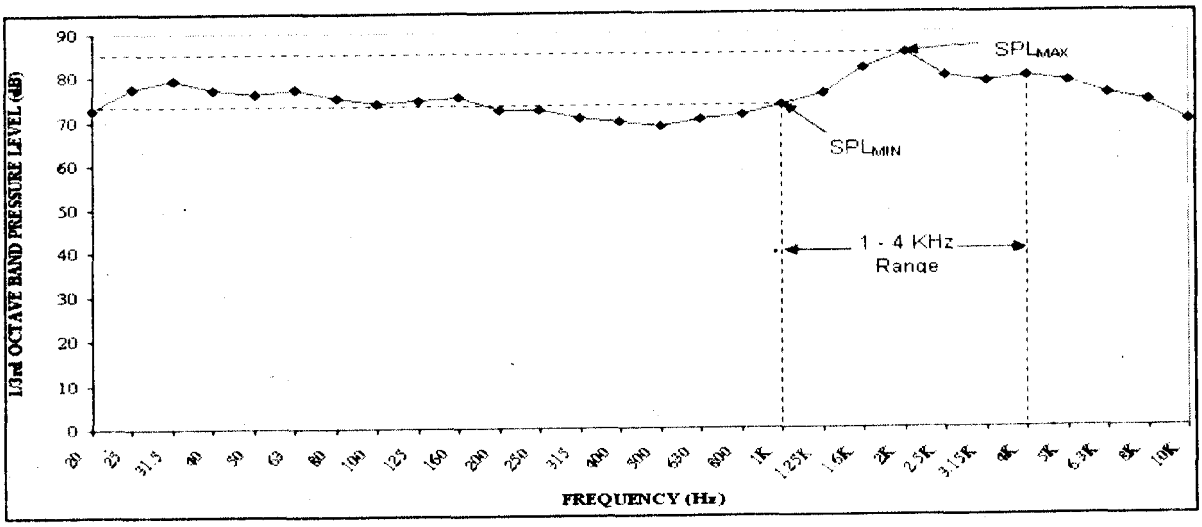

FIGURE 5: Noise Spectrum For Zone 3

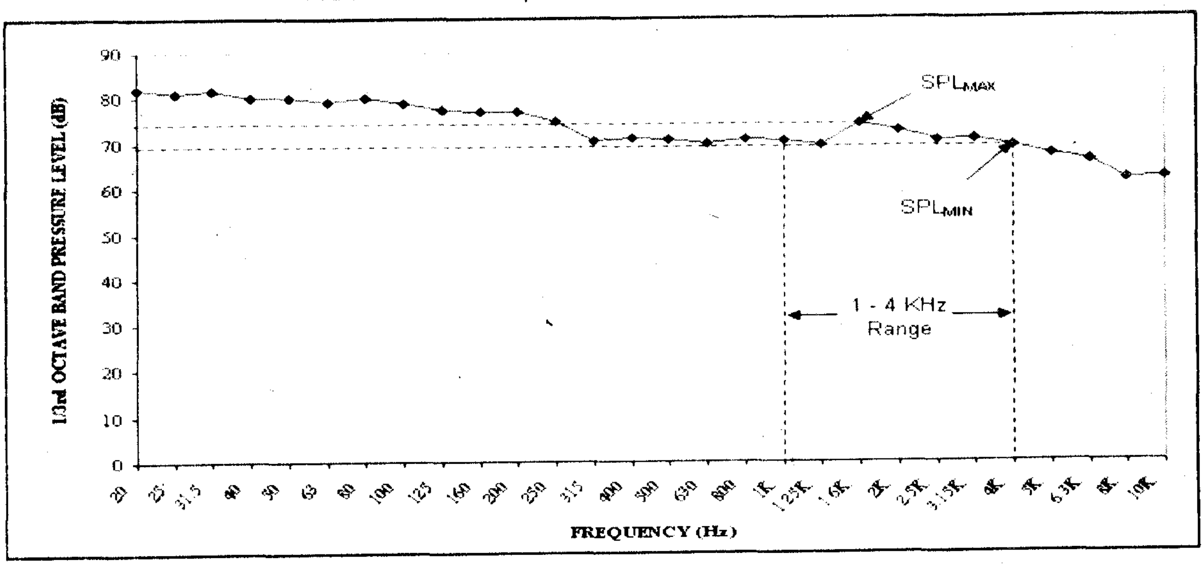

FIGURE 6: Noise Spectrum For Zone 4

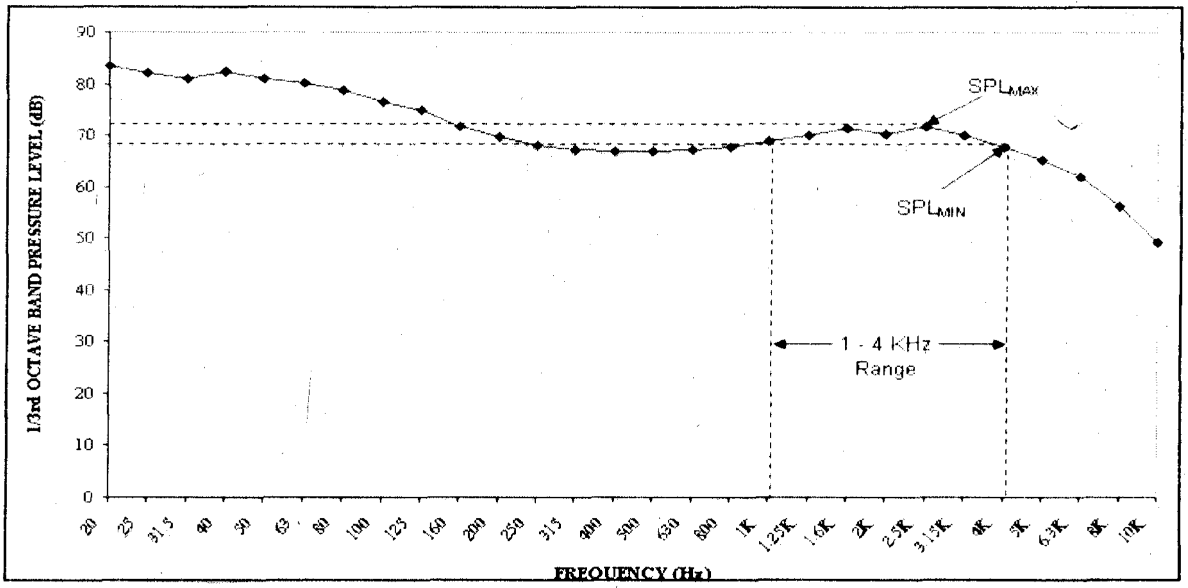

FIGURE 7: Noise Spectrum For Zone 5

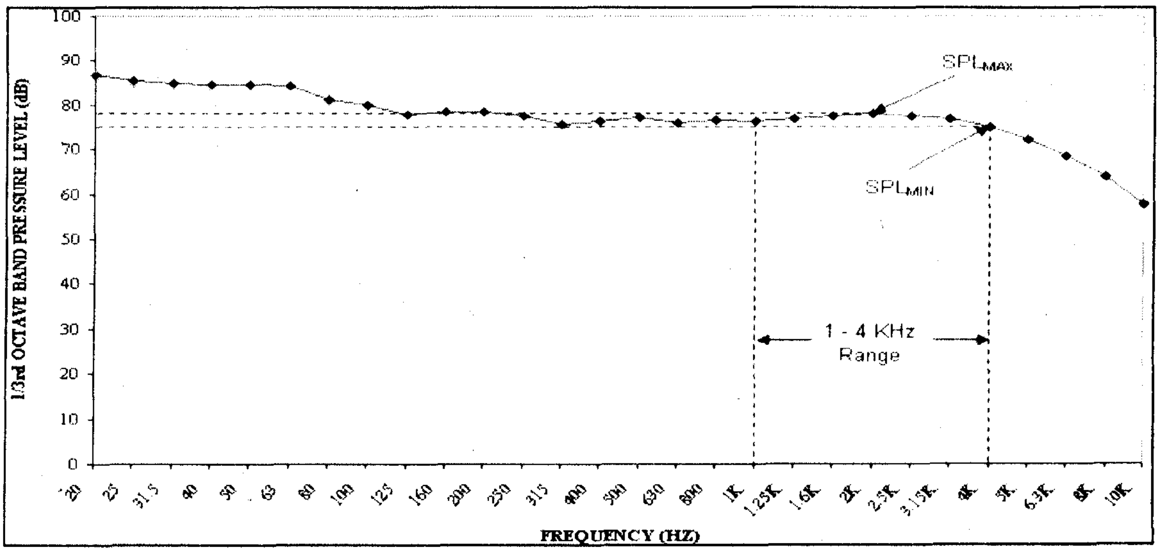

FIGURE 8: Noise Spectrum For Zone 6

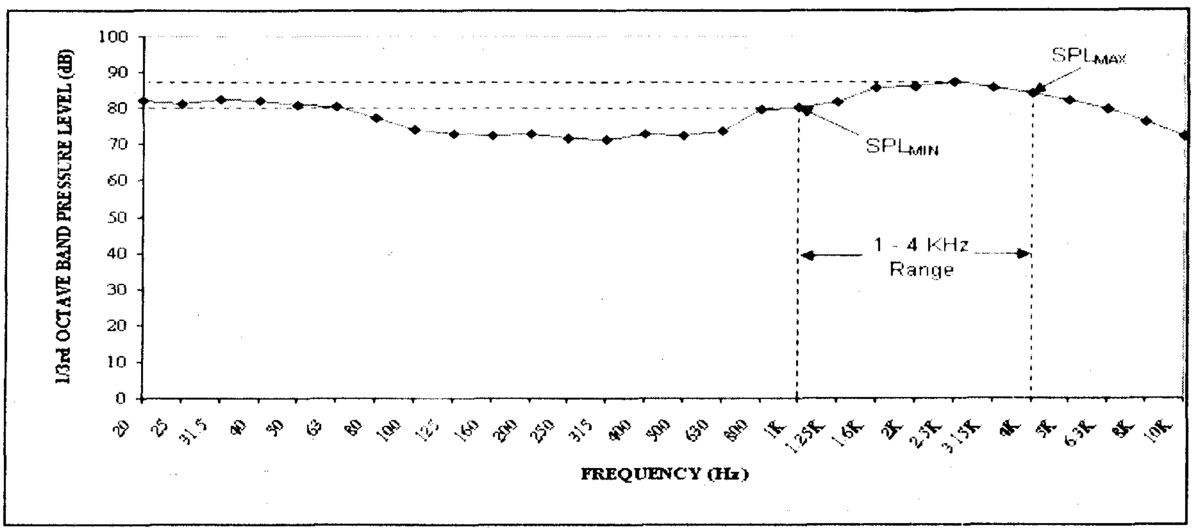

FIGURE 9: Noise Spectrum For Zone 7

In Zone 1 (Office and water utility area) with pumps seldom in operation, a peak mean noise level of 77.4 dB was measured in the 31.5 Hz frequency band while the lowest of 50.7 dB was recorded in the 10 kHz band. For Zone 2 (Trains area) where very heavy duty Kawasaki-Cooper centrifugal compressors, suction scrubbers, filter separators and heavy duty overhead fans operate, the peak value of 89.9 dB was recorded in the 4 kHz band with the lowest of 69.8 dB at 10 kHz. 85.3 dB at 2 kHz and 68.6 dB at 500 Hz were recorded as peak and lowest noise values respectively for Zone 3 (Process area) where condensate and filter separators, mole sieve skids, Turbo-expander recompressors and Reflux drum skid motors operate. 82.1 dB at the 20 Hz band is observed as peak value and 62.1 dB at 8 kHz band as lowest for Zone 4 (Hot oil area). Zones 5 (Pig launcher/Receiver and slug catcher area) and 6 (LPG storage area with only Spherical tanks) similarly recorded peak noise values of 83.5 dB and 86.6 dB respectively at the 20 Hz frequency band and 49.3 dB and 57.7 dB respectively as lowest at the 10 kHz frequency band. Zone 7 (Deluge equipment and Custody meter area) with Rerun and Transfer pumps and Mov skid pumps in operation showed peak value of 87.2 dB at 2.5 kHz and 71.3 dB at 315 Hz as lowest mean noise value.

It was observed that zones 2, 3 and 7 recorded peak noise levels greater than the allowed 85 dB (Mineral Oil (Safety) Regulations, DPR, 1997) and in the range 2– 4 kHz where the normal human ear is most sensitive. This noise level is the starting point where damage risk is thought to be imminent (Croome, 1977). Workers in these zones are prone to severe disruption of conversation by these types of noise sources and possible reduction/loss of intelligibility (Akpan and Onuu, 2004).

Sound pressure levels (Max. – Min.) in the range (1 – 4 kHz), which is a measure of annoyance level were observed to be also high in these zones with zone 2 producing the highest value of 12.7 dB followed by zone 3 having 11.7 dB and zone 7 having 7.3 dB (see Table 1).

TABLE 1: annoyance level of noise spectra for the entire gas plant

ZONES / MEASURE OF ANNOYANCE	1 Office and water utility area	2 Trains area	3 Process area	4 Hot oil area	5 Pig Launcher/Receiver and Sfug Catcher area	6 LPG Storage area	7 Deluge equipment, Custody meter area
SPL (Max. – Min) in the range[1 – 4 Hz](dB)	5.3	12.7	11.7	5.0	3.8	2.9	7.3

This was expected as the higher the difference between the maximum sound pressure level and the minimum sound pressure level in the range 1 – 4 kHz, the higher the annoyance produced with the exception of zone 6 which produced the least annoyance of 2.9 dB even though it recorded peak mean noise greater than 85 dB. This is because of its proximity to the Gas flare area and the absence of the type of machinery that can contribute to high noise at high frequencies. Onuu et al. (1996) previously observed this same trend in their investigation.

A close observation also revealed that the type of noise at Zones 2, 3, and 7 was not entirely discrete frequency noise as would be expected. The noises here have been obscured by random frequency broadband noise emanating from the Gas flare. According to BS 7445 (1991), the tonal (discrete) character of noise may be present where a single 1/3rd Octave band level is at least 5 dB higher than the level in both of the adjacent bands. Noises with broader peaks were observed in these Zones and this would not be judged completely as tonal in character. Conversely, Zone 6 recorded a Broadband type of noise because the noise reaching this area originates from the Gas flare area which is usually low frequency noise (below 50 Hz). There was no discrete frequency tones present in this area because of the turbulent high-velocity airflow which dominates this area. Discrete frequency noise masked by broadband noise was also registered at Zones 1 and 4. Impact noise may not have beer clearly experienced since there were no operations such as dropping of hammer, dropping steel plates, hoppers, vibrating conveyors and presses among others which can generate this type of noise inside this Gas plant.

Zones 1, 4, 5 and 6 are observed to register peak mean noise levels which occupied the low frequency range 20 – 31.5 kHz which may cause harm to body resonance (Abumere, et. al, 1999) especially the head-neck shoulder system (Menkiti, 1994) of workers within these zones.

Figure 10 shows the noise spectra for the entire gas plant. It can be seen that the variation of the band pressure levels with 1/3rd octave band frequencies are such that the spectra tended towards being linear. This shows that the noise within the Plant is fairly Gaussian.

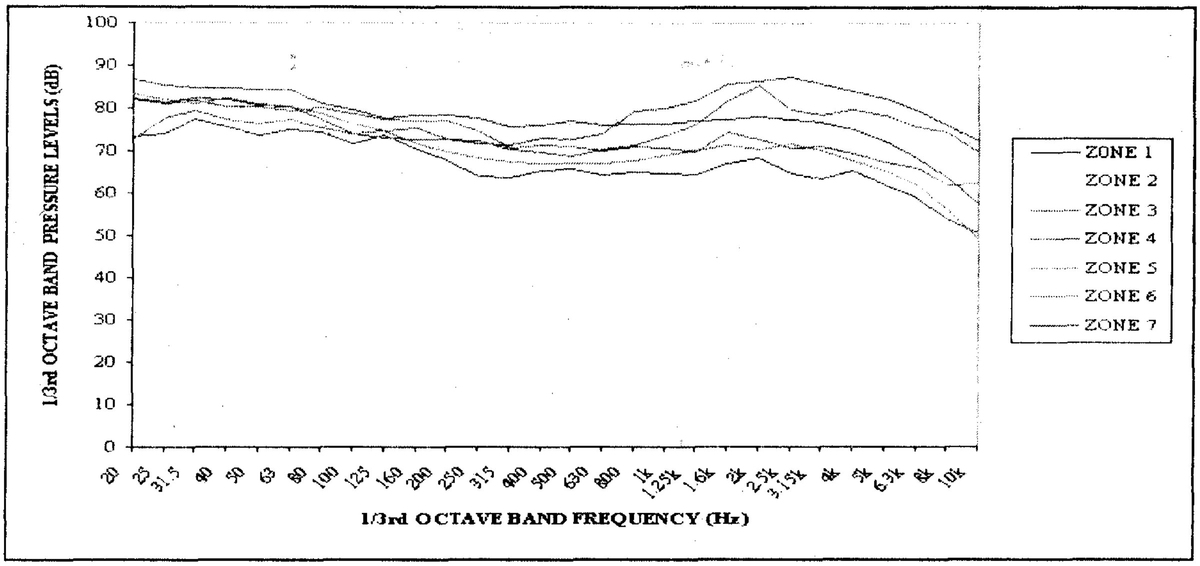

FIGURE 10: Summary of Noise Spectra for The Entire Gas Plant Area

CONCLUSION

The noise condition within this gas plant is such that the high level of discomfort and annoyance were produced by discrete noise masked by broadband noise in the zones where machines with rotating parts operate. This suggests that the machinery is ageing. The generators and plants may need replacement with sound-proof types where possible; the compressors, pumps, process equipment may be housed in acoustic enclosures; the moving parts of machines (gears, bearings, motors and fans) need adequate lubrication and proper anti-vibration mountings. Others zones with discomforting broadband noise and low levels of annoyance had high band pressure levels within the low frequency range resulting from the gas flare. This means that long term exposure to these types of noise can cause permanent damage to hearing or even harmful resonance effects in the head-neck shoulder system of the body of employees within this plant.

To ensure that the environment within such gas plants are acoustically safe and quiet and a place where important instructions are clearly understood, warnings heard and every worker's hearing protected, manufacturers can obtain the noise spectra of various machines and plants and provide to end-users, designers and planners so that a comparison of the data with the spectra of these machines and plants developed later could make possible the detection of flaws since it is likely that these spectra could contain information about the machines operational and structural characteristics.

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