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Review of Noise Suppression in Package Generators

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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Review Article

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ABSTRACT

Review of Noise Suppression in Package Generators is reported. Shortfall in power generation, distribution and availability to the populace in developing economies has compelled the populace to embrace the usage of package generators in their domestic and commercial activities. The attendant noise pollution associated with the package generator usage has become a menace. The Review has identified materials and methods/procedures for evaluating the Noise level, Design and application of Noise Suppression Units (also known as mufflers) and evaluating the optimal noise reduction achieved. The contribution to body of knowledge hopefully stands to minimize the noise pollution of the environment which is detrimental to the health and wellbeing of the society.

Keywords: Package generators; noise suppression; mufflers and audiometry protection.

1. INTRODUCTION

The issues ranging from job creation to energy/power generation, which is the bedrock for the middle class industry/business setup has been on the decline. National responsibility for energy/power generation has been abdicated by many developing economies. Small and medium scale industries/businesses have thereby resorted to seeking alternative and affordable

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sources of power. The only alternative area immediately available to these small and medium scale businesses is the package generator syndrome. These package generators have an advantage in terms of mobility and ease of deployment to business sites; the installation and start up times are equally short. As a disadvantage, these package generators are relatively expensive to run with the current high price regime of petroleum products and fuels; attendant pollution of the environment resulting from flue gas discharge to the environment; and noise and vibration pollution cannot be ruled out. The attendant consequence of the foregoing is that people and the environment are being exposed to noise and vibration pollution in excess of sixteen hours per day. This literature review intends to evaluate the extent of human and environmental exposure to noise and vibrations emanating from the usage of package generators and necessary research done to mitigate the impacts of the exposure to this noise and vibrations.

2. LITERATURE REVIEW

2.1 Sound, Noise and Noise Measurement

Noise and Sound are physically the same, differences arising in their acoustic quality as perceived by listeners. This leads to a definition of noise as undesired sound, whilst physically both noise and sound are similar, acoustic waves, carried on oscillating particles in the air. Sound is detected by the ear in a mechanical process which converts the sound waves to vibrations within the ear and the process which leads to perception and response entails: input signal; detection by the ear; perception by the brain and appropriate response by the brain as a reaction to the perception. Low frequency noise causes extreme distress to a number of people who are sensitive to its effects [1]. Noise is unwanted electrical or electromagnetic energy that degrades the quality of signals and data [2]. Also, Noise can be defined as sound or a sound that is loud, unpleasant, unexpected or undesired [3]. In a similar vein, Noise is seen as anything that interferes with, slows down, or reduces the clarity or accuracy of a communication [4]. On the other hand, Noise could be seen as loud, discordant, or disagreeable sound or sounds [5]. The standard sound level meter is the basic measuring instrument for the industrial hygienist. It consists of a microphone, an amplifier with calibrated volume control and an indicating meter. It measures the root-mean-square (rms) sound pressure level in decibels which is proportional to sound intensity or sound energy flow [6]. Sound level meters of the same type differ mainly in external shape, arrangement of controls, and other convenience features that frequently influence the selection made by a prospective user. Standards for sound level meters specify performance characteristics in order that all conforming instruments will yield consistent readings under identical circumstances. The more important characteristics specified are frequency response, signal averaging and tolerances [6]. Three weighting networks are provided on standard sound level meters in attempt to duplicate the response of the human ear to various sounds. These weighting networks cause the sensitivity of the meter to vary with frequency and intensity of sound like the sensitivity of the human ear. The relative response of the three networks A, B and C mimic ear response to low, medium and high intensity sounds respectively [2]. The A, B and C meter response curves corresponds to the 40, 70 and 100 phon equal loudness contours. The D-weighting network is provided on some sound level meters for approximating the “perceived noise level” used in appraising the offensiveness of aircraft noises. The A-weighting network is the most useful one on the sound level meter. It indicates the A-weighted sound level, often abbreviated dBA, from which most human responses can be predicted quite adequately. The overall accuracy of sound measuring equipment may be checked by using an acoustical calibrator. The acoustical calibration procedure supplements the electrical calibration incorporated in some meters to check the gain of all electronic components following the microphone. The cathode ray oscilloscope is useful for observing the wave form of a sound. It plots the sound pressure versus time on a television-type screen. From observation of the wave shape, it is sometimes possible to determine the mechanical process responsible for the noise. A graphic record of sound level may be obtained by connecting a sound level meter to a graphic level recorder which plots the sound level on a moving paper chart or the magnetic tape recorder can be used to store a sound for later analysis on replay. When sound level varies erratically over a wide range, it is difficult to describe the noise by meter readings, hence statistical analyzers have been developed to assist in this process. The analyzers indicate the percentage of time that the sound level lies in certain predetermined level ranges. From these data, the mean level, standard deviation as well as other statistical indices may be calculated. Another type of monitor evaluates noise exposures according to the rules established by the American Conference of Government Industrial Hygienist (ACGIH). These instruments maybe exposed to varying noise for a work day and will indicate whether this exposure limit has been exceeded [6].

2.3 Acceptability Criteria

Criteria for the acceptability of noise are dictated by the effects which are to be avoided. The most important of these is hearing damage resulting from prolonged exposure to excessive noise. The damaging effect of noise on hearing depends on : i) the level and spectrum of the noise; ii) duration of exposure; iii) how many times it occurs per day; iv) the effects on hearing regarded as damage and v) individual susceptibility to this type of injury. The foregoing factors must be considered in establishing limits of acceptable exposures to dangerous noise. The damage to be avoided was impairment of ability to understand "every day speech" as defined by the medical profession. This medico-legal definition allows some observable change in hearing thresholds not sufficient to affect ability to understand everyday speech significantly. Noise can be classified into steady, intermittent and impulse. Occupational Safety and Health Administration has set 90 dBA as limit for steady exposure to continuous noise, a limit that has become rather widely accepted. On the other hand, interrupting harmful noise allows the ear to rest and recover which reduces the likelihood of permanent damage. Noise exposures that ultimately produce permanent hearing loss also produce temporary hearing loss in normal ears. Conversely, those exposures that do not produce permanent hearing loss do not produce temporary hearing loss in normal ears. [6] while the true relation between temporary and permanent hearing loss has not been established, it is logical to assume that those noise exposures that do not cause much temporary loss will not cause much permanent loss either. Any temporary threshold shift (TTS) that disappears before the next exposure to noise commences is considered acceptable. On the basis of the foregoing assumption, results of TTS studies have been used to define Safe Limits for all day exposures to steady noise. The exposure limits for impulse noise are based on studies of the average TTS caused in normal ears by exposure to various impulses [2]. The American Conference of Governmental Industrial Hygienists (ACGIH) in 1970 adopted the threshold limit value (TLV) for noise. Noise can mask or "blot out' speech sounds reducing the intelligibility of messages. Laboratory studies of these effects have appraised the disruptive potential of the noise by 'speech interference level' which is the average sound pressure level of 500, 1000 and 2000Hz octave bands. The speech interference level is closely related to the A-weighted sound level, and that it is lower by 7 decibels for most common noises. In indoors, noise is likely to become annoying when the A-weighted sound level exceeds 30 dBA in auditoria, or conference rooms, 40 dBA in private offices and homes, or 50 dBA in large offices or drafting rooms. Outdoors, a noise can be expected to prove annoying if it exceeds the background level by 10 dBA or more. Laboratory studies have shown that noise reduces efficiency on some tasks, can upset the sense of balance, and can cause blood vessels to constrict, raising blood pressure and reducing the volume of blood flow. It causes the pupil of the eye to dilate. Even when we are sleeping, noise can cause changes in electro-encephalograms and blood circulation without waking us. Noise can also cause fatigue, nervousness, irritability and hypertension and add to the overall stress of living. There is no convincing evidence so far that any of these effects become permanent and thus deleterious to health. The respiratory system is affected by sounds in the 40 to 60 Hz range because of the resonance characteristics of the chest and that sounds too high in frequency to be heard by the normal ear produce no significant effect when they reach the body by air pathways [6].

Sound pressures well above the pain threshold (about 20 Newton per square metre, N/M^2) are found in many work areas, while pressures down to the threshold of hearing (about $0.00002 N/M^2$) are also of wide interest. This range of more than 10^6 N/M^2 cannot be scaled linearly with a practical instrument because such a scale might be many kilometres in order to obtain the desired accuracy at various pressure levels. In order to cover this very wide range of sound pressures with a reasonable number of scale divisions and to provide a means to obtain the required measurement accuracy at extreme pressure levels, the logarithmic decibel (dB) scale was selected. By definition, the dB is a dimensionless unit related to the logarithm of the ratio of a measured quantity to a reference quantity [7]. Most sound-measuring instruments are calibrated to provide a reading of root-mean-square (rms) sound pressures on a logarithmic scale in decibels. The reading taken from an instrument is called a sound-pressure level (L_p). The term "level" is used because the pressure measured is at a level above a given pressure reference. For sound measurement in air, 0.00002N/M^2 commonly serves as the reference sound pressure. This reference is an arbitrary pressure chosen many years ago because it was thought to approximate the normal threshold of young human hearing at 1000Hz. Sound intensity at any specified location may be defined as the average acoustic energy per unit time passing through a unit area that is normal to the direction of propagation. It is obvious from this definition that sound intensity describes in part characteristics of the sound in the medium, but does not directly describe the sound source itself. The reference intensity commonly used is 10^{-12} watts/m^2. In air, this reference closely corresponds to the reference pressure 0.00002N/M^2 used for sound-pressure levels [7]. On the other hand, sound power (P) is used to describe the sound in terms of the amount of acoustic energy that is produced per unit time. Sound power may be related to the average sound intensity produced in free-field conditions at a distance r from a point source. Sound pressure levels cannot be added arithmetically because addition of these logarithmic quantities constitutes multiplication of pressure ratios. To add sound-pressure levels, the corresponding sound pressures must be determined and added with respect to existing phase relationships. A good procedure for adding a series of dB values is to begin with the highest levels so that calculations may be stopped when lower values are reached which do not add significantly to the total [7].

2.4 Noise Propagation Characteristics

For standard free-field conditions, the sound-pressure level L_p at a given distance r from a small omni-directional noise source can be written in terms of the sound level Lp of the source. Many noise sources have pronounced directional characteristics; that is, they will radiate more noise in one direction than another. Therefore, it will be necessary for the equipment manufacturer to provide the directional characteristics of the source, as well as the power levels, to predict the sound-pressure levels. The directional characteristics of the source are generally given in terms of the directivity factor Q. Q is defined as the ratio of the sound power of a small, omni-directional, imaginary source to the sound power of the actual source where both sound powers produce the same sound pressure level at the measurement position [7].

On the other hand, the acoustical characteristics of a room are strongly dependent upon the absorption coefficients of its surface area. A surface that absorbs all energy incident on its surface is said to have an absorption coefficient of one, while a surface that reflects all incident energy has an absorption coefficient of zero. The absorption coefficient depends upon the nature of the materials, the frequency characteristics of the incident sound. The absorption coefficient is expressed in terms of the fraction of the energy absorbed by the material under the conditions described. A rule of thumb that may be used to determine the amount of noise reduction possible from the application of acoustically absorbent material on the room surface can be formulated, where the absorption units are the sum of the products of surface areas and their respective noise absorption coefficients. Absorption units are commonly expressed in terms of the Sabin, which is the equivalent of one square foot of a perfectly absorptive surface [7].

2.5 Transmission Loss (TL) of Barriers

Sound transmission loss (TL) through a barrier may be defined as ten times the logarithm (to the base 10) of the ratio of the acoustic energy transmitted through the barrier to the incident acoustic energy. TL of a barrier may also be defined in terms of the sound pressure level reduction afforded by the barrier [7].

2.6 Physiology of Hearing

The basic function of the hearing mechanism is to gather, conduct and perceive sounds from the environment. The human voice and other ordinary sounds are composed of fundamental tones modified by harmonic overtones. Our hearing sensitivity is greatest in child hood, but as we get older, our perception of high tones worsens, a condition labeled "presbycusis". The frequency range of the human ear extends from as low as 16 Hz to as high as 30000 Hz. From a practical standpoint however, few adults can perceive sounds above 11,000 Hz. Sound reaches the ear by three routes: i) Air conduction through the ossicular chain to the oval window; ii) Bone conduction directly to the inner ear and iii) conduction through the round window. Under ordinary conditions, bone conduction and the transmission of sound through the round window are less significant than air conduction in the hearing process [8]. Furthermore, the conversion of mechanical energy of sound into electrochemical activity is called transduction. The vibration of the basilar membrane causes a pull, or shearing force of the hair cells against the tectorial membrane. This to and fro bending of the hair cells activates the neural endings so that sound is transformed into an electrochemical response. It remains to be clarified whether an electrical and/or chemical process stimulates the neural endings [8]. Consequent on the foregoing, loss of hearing can be classified into the following categories: i) conductive impairment; ii) sensorineural impairment; iii) mixed (both conductive and sensorineural); iv) central impairment and v) psychogenic impairment [4].

2.7 Audiometry

The audiometer is the fundamental tool used in industry to evaluate a person's hearing sensitivity. It produces tones which vary in frequency usually from 250 Hz to 800Hz at octave or half-octave intervals. The intensity output from the audiometer can vary from zero dB to 110 dB and is often marked "hearing loss" or "hearing level" on the audiometer. Zero dB or zero reference level on the audiometer is the average normal hearing for different pure tones and varies according to the "standard" to which the audiometer is calibrated. Zero reference levels have been obtained by testing the hearing sensitivity of young healthy adults and averaging that sound intensity at specific frequencies at which they were just perceptible. The audiogram serves to record the results of the hearing tests. A graphic description of the faintest sound audible is obtained by plotting the intensity against the frequency [8].

2.8 Effect of Excessive Noise Exposure

Since the ear does not have an overload switch or a circuit breaker, it has no option but to receive all the sound that strikes the ear drum. In industry, excessive noise constitutes a major hazard and such exposure can cause auditory and extra-auditory effects. Noise induced hearing loss (NIHL) can happen unnoticed over a period of years. At first, excessive exposure to harmful noise causes auditory fatigue or temporary threshold shift (TTS). This shift refers to the difference in one's hearing sensitivity measured before and after exposure to sound. It is called "temporary" since there is a return to the individual's pre-exposure hearing level after a period of hours away from the intense sound. However, repeated insults of excessive noise can transform this TTS into a permanent threshold shift (PTS). In fact, studies substantiate that the hearing sensitivity of factory workers in heavy industry is poorer than that of the general population. Many factors influence the course of NIHL. [8] The overall "decibel level" of the noise exposure is obviously important. If a noise exposure does not cause auditory fatigue, then such exposure is not considered harmful to one's hearing sensitivity. Another consideration is the "frequency spectrum" of the noise. Noise exposure which has most of its sound energy in the high frequency bands is more harmful to workers hearing sensitivity than low frequency noises. Another factor is the daily "time distribution" of the noise exposure. In general, noise which is intermittent in character is less harmful to hearing than steady state noise exposure. As the "total work duration"(years of employment) of a worker to hazardous noise is increased, so too does the incidence and magnitude of his NIHL. However, no report of "total" hearing loss has been attributed to excessive noise exposure alone. The "susceptibility" of the worker to hazardous noise must be considered, since not every individual will suffer identical hearing impairment if exposed to the same noise intensity over the same time period. A small percentage of workers will be highly susceptible or on the other hand, refractory to the degrading effects of noise [8].

2.9 Control of Noise Exposure

From an engineering control standpoint, the first step in a hearing conservation programme is to measure the noise levels in all working areas. Areas in which the noise level does not exceed 90 dBA need not be considered further since noise reduction is not required. In area where the noise level does exceed 90 dBA, a study should be made to determine the actual worker exposure time: a) measure noise level; b) determine exposure time and c) evaluate extent of hazard [9]. If the combination of noise level and exposure time indicates that government criteria are exceeded, an evaluation should be made to determine the most economical solution to the problem. Considerations for making such an evaluation are: a) reduction of noise level; b) reduction of exposure time; c) segregation of worker from noise; d) substitution of more-quiet machine or process; e) provision of worker with personal protection such as ear muffs or plugs. Under the Occupational Safety and Health Act, this later option is available only if others fail. The mode of attacking a noise problem is somewhat analogous to that of controlling any environmental hazard. In analyzing a noise problem, one must consider that sound from a source can travel by more than one path to the point at which it becomes objectionable. Therefore noise flow diagrams are a definite aid to accurate analysis of a given problem [9]. The following outline can be used in making such an analysis: Noise Control Analysis Outline: I) Plant Planning. II) Substitution: a) use quieter equipment; b) use quieter process; c) use quieter materials. III) Modification of the Noise Source: a) reduce driving force on vibrating surface: i) maintain dynamic balance; ii) minimize rotational speed; iii) increase duration of work cycle; iv) decouple the driving force; b) reduce response of vibrating surface: i) add damping; ii) improve bracing; iii) increase stiffness; iv) increase mass and v) shift resonant frequencies; c) reduce area of vibrating surface: i) reduce overall dimensions; ii) perforate surface; d) use directionality of source; e) reduce velocity of fluid flow and f) reduce turbulence. IV) Modification of the Sound Wave: a) confine the sound wave and b) absorb the sound wave; i) absorb sound within the room; ii) absorb sound along its transmission path. [9] One of the dominant design considerations in the ultimate solution package sees the typical enclosure design as an optimization of noise control and thermal insulation [10]. Generator Noise Control combines all of these strategies into convenient package that provides weather protection as well as sound attenuation [11]. These generators have noise reduction capabilities and are full weather capable, being entirely Aluminium encased with Aluminium installation hardware [12]. Noise reduction \solutions to the power sector is being rendered and this solution is equally available to individual aspects or a complete package for generator set installation [13]. A feasibility of a simple and effective design of an acoustic enclosure for a portable generator aimed at reducing the radiated noise is presented. This effort is a multi-disciplinary work that comprises acoustics, heat transfer and materials science. Some investigation revealed how generator set noise is propagated, controlled and reduced to a limit as defined statute: the design is a balance of noise control and thermal management. Noise generating areas have been identified and convectional passive noise control techniques have been used to control and reduce the noise. Acoustic barriers and insulation are used to control the noise propagation at its transmission path [14]. In a typical investigation carried out, an overall noise reduction of 8.5dB (A) was obtained on side 4 of the generator set as a result of the implementation of all the noise control measures [15]. In another development, an active noise control system for de-noising the inter communication signal of an airplane cockpit is proposed. Noise sources such as engines degrade the quality of the intercommunication signal, especially in the case of the pilot and co-pilot headsets. A two microphone active adaptive noise controller is designed by using an adaptive FIR filter in an active structure. The designed system is simulated and also implemented in real environment using real speech signals, periodic noise and AWGN noise. The obtained results showed competent functionality and performance of the proposed system. This ICS noise removal architecture can be used on any cargo, civil or fighter platform (such as C-130, IR-AN 140 and F5-F) and also in radar and electronic warfare (EW) systems (for clutter/interference compensation) with minimum hardware or software changes [16]. In similar vein, an invention includes a method, apparatus and computer program to selectively suppress wind noise while preserving narrow-band signals in acoustic data. Sound from one or several microphones is digitized into binary data. A time-frequency transform is applied to the data to produce a series of spectra. The spectra are analyzed to detect the presence of wind noise and narrow band signals. Wind noise is selectively suppressed while preserving the narrow band signals [17]. Also, small engines may require sound proofing to eliminate one or more of the following effects: hearing loss, speech interference, community annoyance, detectability and psychological disorientation. Detectability criteria are frequently associated with military applications and may require the use of a sound proof enclosure in addition to other engine treatments. Acoustical noise sources are conveniently classed as either aerodynamics or mechanical. Aerodynamic sources are predominant on small engines. Treatment of exhaust noise by individual components, for example muffler, is inadequate, a system approach, through the use of an electro-acoustic analog computer, has proved to be a much more satisfactory procedure. To develop a sound proof enclosure for a 0.3 KW military engine-generator set, several control techniques were required: (1) the enclosure had to be decoupled from the engine, (2) the panel structures had to have a high transmission loss (achieved through the careful selection of damping material), (3) cooling air inlet ducts and exhaust gas outlet ducts had to be properly treated to minimize noise conduction. The degree of noise reduction attainable was limited by specifications for size, weight, engine cooling at high ambient temperatures, and engine accessability for starting and fueling [18]. Systems and methods for adaptive intelligent noise suppression are provided. In exemplary embodiments, a primary acoustic signal is received. A speech distortion estimate is used to derive control signals which adjust an enhancement filter. The enhancement filter is used to generate a plurality of gain masks, which may be applied to the primary acoustic signal to generate a noise suppressed signal [19]. In another development, power integrity design has become important in the advanced CMOS digital systems, because power supply noise induces logic instability and electromagnetic radiation. Especially, anti-resonance peaks in power distribution network (PDN) due to the chip-package interaction induce the unwanted power supply fluctuation, and result in large electromagnetic radiation. Effects of damping condition of the total PDN impedance on power supply noise have been studied by adding variable on-die RC circuit to the intrinsic on-die RC circuit in chip PDN. Two types of test chips were designed with different variable on-die PDN impedances. By varying the values of on-die RC circuits, the stimulated waveforms of power supply noises for the two test chips have been changed from oscillatory region to damped regions [20]. Also, a method and apparatus for generating noise to be used in evaluation and testing of digital or analogue integrated circuits is reported. One or more noise generators fabricated on a substrate generate noise representative of the digital switching noise generated by a digital integrated circuit. The noise generator may be programmable to generate noise over a wide frequency and amplitude range. In addition, a plurality of noise generators may be used to independently and simultaneously generate noise signals with multiple frequencies and amplitudes. A test circuit either analogue or digital is fabricated on the same substrate. The generated noise(s) are generated for use in the evaluation and testing of the effects of the noise on the analogue or digital test circuit [21]. In similar vein, imaging apparatus including a solid state sensor and a noise suppression circuit formed by a first and second sample and hold circuits and different amplifier for suppressing noise in a video output signal generated by the image sensor is presented [22]. Also, World Intellectual Property Organization (WIPO) assigned patent to Mitsubishi Electric for Noise Suppression Device. The noise suppression device is provided with: an input signal analysis unit for analyzing the harmonic structure and the periodicity of an input signal on the basis of the power spectra of a plurality of input signals; a power spectrum synthesis unit for synthesizing the power spectra of the plurality of input signals and generating a synthesized power spectrum in accordance with the analysis results from the input signal analysis unit; a noise suppression amount calculation unit for calculating the amount of noise suppression on the basis of the synthesized power spectrum generated by the power spectrum synthesis unit and an estimated noise spectrum estimated from the input signal; and a power spectrum suppression unit for suppressing noise for the synthesized [23]. A method of processing raw banded gains for applying to an audio signal, an apparatus to generate banded post-processing gains, and a tangible computer-readable storage medium comprising instructions that when executed carryout the method is presented. The raw banded gains are determined by input processing one or more input audio signals. The method includes applying post processing to the raw banded gains to generate banded post processed gains, generating a particular post-processed gain for a particular frequency band, including median filtering using raw gain values for frequency bands adjacent to the particular frequency band. One or more properties of the post-processing depend on classification of the one or more input audio signals [24]. On a similar note, the performance of a speech recognition system degrades rapidly in the presence of ambient noise. To reduce the degradation, a degradation model is proposed which represents the spectral changes of speech signal uttered in noisy environments. The model uses frequency warping and amplitude scaling of each frequency band to simulate the variation of format location, format bandwidth, pitch, spectral tilt and energy in each frequency band by Lombard effect. Another Lombard effect, the variation of overall vocal intensity is represented by a multiplicative constant term depending on spectral magnitude of input speech. The noise contamination is represented by an additive term in the frequency domain. According to this degradation model, the cepstral vector of clean speech is estimated from that of noisy Lombard speech using spectral subtraction, spectral magnitude normalization, band-pass filter in LIN-LOG spectral domain, and multiple linear transformations. Noisy Lombard speech is collected by simulating the noisy environments using noises from automobile cabins, an exhibition hall, telephone booths in downtown, crowded streets and computer rooms. The proposed method significantly reduces error rates in the recognition of 50 Korean words. For example, the recognition rate is 95.91% with this method and 79.68% without this method at SNR (Signal-to-Noise Ratio) 10 dB [25]. On the other hand, the first experimental observation of piezoelectricity and the piezotronic effect in an atomically thin material, Molybdenum disulfide, resulting in a unique electric generator and mechanosensation devices that are optically transparent, extremely light and very bendable and stretchable is reported from the School of Engineering and Applied Science of Columbia University and the Georgia Institute of Technology. For the nature study, Hone's team placed thin flakes of M_oS_2 on flexible plastic substrates and determined how their crystal lattices were oriented using optical techniques. They then patterned metal electrodes onto the flakes. In the research done at Georgia Tech, Wang's group installed measurement electrodes on samples provided by Hone's group, then measured current flows as the samples were mechanically deformed. They monitored the conversion of mechanical to electrical energy and observed voltage and current outputs. The researchers also noted that the output voltage reversed sign when they changed the direction of applied strain and that it disappeared in samples with an even number of atomic layers. The presence of piezotronic effect in odd layer M_oS_2 was also observed for the first time [26]. In order to provide noise suppression, bumps or undulations are provided on a nozzle surface in order to vary the convergent-divergent ratio between that surface and an opposed nozzle surface. By such an approach, a circumferential variation in shock cell pattern is created and the flow is deflected so as to enhance turbulent mixing thereby suppressing noise [27]. On the other hand, Active Control is sound field modification, particularly sound field cancellation, by electro-acoustical means. In its simplest form, a control system drives a speaker to produce a sound field that is an exact mirror-image of the offending sound (the "disturbance"). The speaker thus "cancels" the disturbance and the net result is no sound at all. In practice, of course, active control is somewhat more complicated. The name differentiates "Active Control" from traditional "Passive" noise treatment method for controlling unwanted sound and vibration. Passive noise control treatment include: "insulation", silencers, vibration mounts, damping treatments, absorptive treatments such as ceiling tiles, and conventional mufflers like the ones used on today's automobiles. Passive techniques work best at medium and high frequencies, and are important to nearly all products in today's increasingly noise-sensitive world. The size and mass of passive treatments usually depend on the acoustic wavelength, making them thicker and more massive for lower frequencies. The light weight and small size of active systems can be a critically important benefit. Active Control Demo should include:

i) Noise cancellation Demo,
ii) Building an analogue feedback controller,
iii) Building Ostergaard's feedback vibrator controller,
iv) Buying an off-the-shelf active control module and
v) Modifying an active control headset [28].

An audio signal in a hearing aid is enhanced by detecting the power of the desired audio signal and the power of the total audio signal, generating a power value and making a noise reduction adjustment or no noise reduction adjustment based on the power value. In one embodiment, the power value is a function of the total power of the audio signal. In a second embodiment, the power value is a function of the ratio of the power of the desired audio signal to the power of the total audio signal. When the noise reduction is accomplished with beam forming, the invention uses a direction estimate vector in combination with a beam intensity vector, which is based on the power value to generate a beam forming gain vector. The direction estimate vector is scaled by the beam intensity vectors, the product of the vectors is the beam forming gain vector. The beam forming gain vector is multiplied with the left and right signal frequency domain vectors to produce noise reduced left and right signal frequency domain vectors [29]. The first circuit implementation of quantization suppression technique for Delta sigma fractional-N frequency synthesizers using reduced step size of frequency dividers is presented. This technique is based on a 1/1.5 divider cell which can reduce the step size of the frequency divider to 0.5 and thus the reduced step size suppresses the quantization noise by 6 dB. This frequency synthesizer is intended for a WLAN 802.11a/WIMAX 802.16e transducer. This chip is implemented in a 0.18mm CMOS process and the die size is 1.23 mm times 0.83 mm. The power consumption is 47.8mw. The in-band phase noise of -100dBc/Hz at10KHz offset and out-of-band phase noise of -124dBc/Hz at 1MHz offset are measured with a loop bandwidth of 200 KHz. The frequency resolution is less than 1Hz and the lock time is smaller than 10 mus [30]. The ability to find quiet times and places is essential to support complex knowledge work, while the ability to have planned or spontaneous interactions without disturbing others is necessary for team work and relationship development. "Acoustical comfort" is achieved when the workplace provides appropriate acoustical support for interaction, confidentiality and concentrative work. The foundation of acoustical comfort in the office is the "Privacy Index" (PI). A privacy index of 80 defines normal privacy. General Services Administration (GSA) work place 20.20 research programme revealed that 60% of 3700 respondents said that they could get more work done if it were quieter. 56% said the ability to insulate themselves from distractions was very important while 50% said noise keeps them from being as productive as they could be. Three key areas of equal importance which need to be addressed to create acoustic comfort have been identified as: Behavior, Design and Acoustic Treatment. Consequently, integrating all three areas will deliver a work place that is comfortable, sustainable, and supportive of both interactive and quiet work [31]. In another development, the authors hypothesized cardiovascular effects in paper industry workers exposed to noise. The study included 72 paper industry workers exposed to noise and two control groups not exposed to noise. The workers completed questionaires and did medical examinations, measurement of blood pressures, electrocardiogram, blood tests, audiometry and measurement of noise exposure. The workers exposed to noise all hearing impaired, were compared with those not exposed and results show: significant increase of mean systolic and diastolic blood pressure (P,0.001), higher frequency of hypertension, systolic and diastolic pressure (P,0.01 and P,0.001) and electro-cadiografic abnormalities (P,0.05), significant reduction of blood pressure response in orthostatism (P,0.005). The results suggest that for the workers of the paper industry the noise is an occupational risk factor for cardiovascular effects [32]. Noise figure is a figure-of-merit that describes the amount of excess noise present in a system. Minimizing noise figure reduces system impairments that result from noise. In our personal lives, noise degrades the image quality of TV pictures and adversely impacts the voice quality of cell phone calls. In military applications like radar, receiver noise limits the effective range of the system. With digital communications, noise increases the bit -error rate. System designers always try to optimize the overall signal-to- noise ratio (SNR) of the system. This can be done by increasing the signal or by reducing the noise. In a transmit/receive system like a radar system, one possibility is to increase the radar's transmitted power by using bigger, more powerful amplifiers, and/or by using larger antennas. Decreasing the path loss between the transmitter and receiver also helps SNR, but path loss is often defined by the operating environment and cannot be controlled by the system designer. The noise factor (F) of a network is defined as the input SNR divided by the output SNR:

$$F = (S_I/N_I)/(S_o/N_o)$$

Where,

S_I = input signal power,
S_o = output signal power
N_I = input noise power
N_o = output noise power.

Noise figure (NF) is simply the noise factor expressed in decibels: NF = 10*log(F) [33]. The Federal Energy Regulatory Commission (FERC) of the USA currently requires that all new compressor stations under its jurisdiction meet an L_{dn} of 55dB at the nearest noise sensitive area. Where L_{dn} = day/night average sound level [34]. In another development, Bernoulli between some stations 1 and 2 gives:

$$P_1/\Upsilon + v_1^2/2g + z_1 = p_2/\Upsilon = v_2^2/2g + z_2 + h_e \quad (1)$$

Where h_e =head loss in fluid due to expansion = $v_1^2/2g(1-A_1/A_2) = v_1^2/2g(1-D_1/D_2) = K_e = v_1^2/2g$.

For pipes in series, total head loss h_f is sum of losses at points 1, 2, 3 and 4. In similar vein, for pipes in parallel, Head loss from A to B, is same as for pipes 1, 2 and 3, that is

$$h_{f(A-B)}=4f_1L_1v_1^2/D_1^2g=4f_2L_2v_2^2/D_2^2g = 4f_3L_3v_3^2/D_32g \quad (2)$$

$$Q_0 = Q_1 + Q_2 + Q_3 \quad (3)$$

$$P_A/\Upsilon+V_A^2/2g+z_A=p_B/\Upsilon+v_B^2/2g+Z_B +4f_1L_1v_1^2/D_12g \quad (4)$$

$$= + 4f_2L_2v_2^2/D_22g \quad (5)$$

$$= + 4f_3L_3v_3^2/D_32g \quad (6)$$

The last terms of equations 4, 5 and 6 must be equal [35]. Consequent on a design based on selected materials parameters in line with the foregoing, the Noise suppression unit can be designed and fabricated. The summary of the Literature Review is as detailed in Table 1 below.

Table 1. Summary of Literature review

S/no	Literature review key points	Reference number1
1	Noise and Sound are physically the same, differences arising in their acoustic quality as perceived by listeners. Low frequency noise causes extreme distress to a number of people who are sensitive to its effects.	[1]
2	The standard Sound Level Meter is the basic measuring instrument for the industrial hygienist. It measures the root-mean-square (rms) sound pressure level in decibels which is proportional to sound intensity or sound energy flow. Aiding tools for analysis are: graphic level recorder, magnetic tape recorder and magnetic analyzers. The analyzers indicate the % of time that the sound level lies in certain predetermined level ranges. Monitor evaluates noise exposures for a work day versus exposure limits (ACGIH). The damaging effect of noise on hearing depends on: (i) level and spectrum of noise (ii) duration of exposure (iii) how many times it occurs per day (iv) the effects on hearing regarded as damage and (v) individual susceptibility to this type of injury. Noise could be classified into steady, intermittent and impulse states.	[6]
3	The sound absorption coefficient depends upon the nature of the materials, the frequency characteristics of the incident sound. Sound absorption units are the sum of the products of surface areas and their respective noise absorption coefficients.	[7]
4	Loss of hearing can be classified into the following categories: (i) conductive impairment (ii) sensorineural impairment (iii) mixed impairment (both conductive and sensorineural), (iv) central impairment and (v) psychologenic impairment.	[4]
5	The audiogram serves to record the results of the hearing tests. A graphic description of the faintest sound audible is obtained by plotting the intensity against the frequency.	[8]
6	Exposure to harmful noise causes auditory fatigue or temporary threshold shift (TTS) which on the long run lead to permanent threshold shift (PTS). Control of Noise Exposure entails: i) measuring noise level, ii) determination of exposure time and iii) evaluating extent of hazard. If the combination of noise level and exposure time indicates that government criteria are exceeded, an evaluation should be made to determine the most economical solution to the problem. Consideration for making such an evaluation are: a) reduction of noise level, b) reduction of exposure time c)segregation of worker from noise, d) substitution of more quiet machine or process e) Providing workers with personal protection such as ear muffs or plugs. Noise control analysis outline entails: I) plant planning II) substitution (a) use quieter equipment, (b) use quieter process, (c) quieter materials. III) modification of the noise source (a) reduce driving force on vibrating surface: (i) maintain dynamic balance, (ii) minimize rotational speed, (iii) increase duration of work cycle, (iv) decouple the drive; (b) reduce response of vibrating surface (i) add damping, (ii)improve bracing, (iii) increase stiffness, (iv) increase mass, (v) shift resonant frequencies. (c) reduce area of vibrating surface (i) reduce overall dimensions, (ii)perforate surface (d) use directionality of source, (e)reduce the velocity of fluid flow and (f) reduce turbulence. IV) Modification of the sound wave. A) Confine the sound wave and b) absorb the sound wave (i) absorb sound within the room, (ii) absorb sound along transmission path.	[9]

S/no	Literature review key points	Reference number1
7	Enclosure design as an optimization of noise control and thermal insulation. Active noise control system. Acoustical noise sources are conveniently classed as either aerodynamics or mechanical. Aerodynamic sources are predominant on small engines.	[10]
8	Noise suppression Device invented	[23]
9	A degradation model is proposed which represents the spectral changes of speech signal uttered in noisy environment.	[25]
10	Piezoelectricity and piezotronic effect of an atomically thin material molybdenum disulfide resulting in a unique electric generator	[26]
11	Noise suppression through bumps or undulations on a nozzle surface	[27]
12	Differentiated "Active Control" and "Passive" noise treatment method for controlling unwanted sound and vibration. Passive noise control treatment include: "insulation", silencers, vibration mounts, damping treatments, absorptive treatments such as ceiling tiles, and conventional mufflers. Active control Demo should include: (i) noise cancellation Demo, (ii) building an analogue feedback controller, (iii) building Ostergraard's feedback vibration controller, (iv) buying an off-the -shelf active control module and (v) modifying an active control headset.	[28]
13	Beam forming invention to reduce noise	[29]
14	Invention for the suppression of the quantization noise	[30]
15	Relates "Acoustic Comfort" to "Privacy Index"	[31]
16	Relates cardiovascular effects to noise exposure.	[32]
17	Noise Figure (is a figure of merit) that describes the amount of excess noise present in a system. The noise factor (F) of a network is defined as the input SNR divided by the output SNR. Noise figure (NF) is the noise factor expressed in decibel. NF = 10*log (F).	[33]

3. DISCUSSION

Leventhall G et al. [1] has distinguished between Sound and Noise and [1] and [6] have classified the damages that occur to human beings as a result of excessive exposure to noise. Ter C et al. [32] has related cardiovascular effect to noise exposure. In the same vein, [31] has related "Acoustic Comfort" to "Privacy Index". The damaging effect of noise on hearing as listed by [4] and [6] agree with the values given by [ACGIH], which form the basis for the establishment of exposure limits [Threshold Exposure Limits Values (TLV) and Short Time Exposure Limits (STEL)]. Michael IP [7] investigated Sound Absorption materials and the frequency characteristics of the incident sound and relating these quantities to noise absorption coefficients. In a similar vein, [8] indicated the importance of the Audiogram as a recorder of the results of hearing tests. On the other hand, [9] advanced that in order to defend personnel against harmful noise that leads to temporary threshold shift (TTS) and permanent threshold shift (PTS), Noise control analysis should be done. In the words of [9], such noise control analysis outline entails:

I) Plant Planning
II) Substitution: a) Using quieter machines, b) Using quieter process, c) Using quieter materials.
III) Modification of the noise source: a) reducing drive force on vibrating surface - this entails the maintenance of dynamic balance, minimizing rotational speed, increasing duration of work cycle and decoupling the drive; b) reducing the response of vibrating surface by adding damping, improving bracing, increasing stiffness, increasing mass, shifting resonant frequencies; c) reducing area of vibrating surface by reducing overall dimensions, perforating surface; d) using directionality of source; e) reducing the velocity of fluid flow and f) reducing of turbulence.
IV) Modification of the sound wave: a) confine the sound wave and b) absorb the sound

wave: i) absorb sound within the room, ii) absorb sound along transmission path.

Of course, all the methods listed above by [9] as control of noise exposure have been tested and put into practice in various industries. A navigational trip around Thermal Power Plants and Turbo Blower Stations (TPP-TBS), Iron and Steel Making Shops, Aluminium Smelting companies, Bamburies in Tyre manufacturing companies among others reveal the presence of one or combination of the methods of noise control as stipulated by [9]. Some of these noise control applications can be found in Boiler, Turbo Generators and Turbo Blowers, large Gas engines of ratings 1.5 MW and above. These noise control applications are most favoured in machinery and equipment sited in permanent locations in contrast to mobile, versatile and multipurpose equipment such as package generators which could be deployed to various outdoor operations within minimal time requirements. The limited usage of the noise control applications on mobile package generators could possibly be adduced to light weight and ease of maneuvering considerations among other factors. However, [10] investigated Enclosure design as an optimization of noise control and thermal insulation. Active noise control system was also investigated by [10] which led to the conclusion that Aerodynamic sources (of Acoustic noise) are predominant on small engines. It is to be noted that enclosure design adds to the overall weight of the generator or machine. Moreover, the enclosure of the generator with the view of noise control and thermal insulation leads to a lot of retention of heat within the compartment of the generator or machine. Hence generator unit require special forced cooling/ventilation method in order to dissipate the trapped heat in its body. These accessories will increase the budget and gross weight of generator. On the alternative, [23] invented the Noise Suppression Device which could lead to the attenuation of noise. This is definitely a welcome development, since the advantages of application of this method may likely outweigh the other methods. Further investigation may therefore be conducted to see how this method of noise suppression could be adapted to the package generators. Also, the possibility of the adaptation of [25]'s Degradation Model of spectral changes of speech signal uttered in noisy environment to the package generator environment could be considered. As an alternative to package generators, [26] investigated the Piezoelectricity and piezotronic effects of an atomically thin material Molybdenum disulfide in a unique electric generator. By the outcome of this investigation, noise generation as associated with package generators will be nonexistent. It is therefore important that further research be done in this area to achieve the desired result in the shortest future. Furthermore, the beam forming invention to reduce noise by [29] and invention for the suppression of the Quantization noise by [30] form a major contribution to Active control of noise. [28] differentiation of noise treatment method for controlling unwanted sound and vibration into "Active Control" and "Passive Control" has oversimplified the noise management regime. From the standpoint of the information provided in this literature review, economics, environment of usage, mobility and versatility of the package generator, the "Passive Control" method for noise should be considered as the first line of action.

4. CONCLUSION

Noise is detrimental to the society's health and wellbeing. As of today, the use of package generators is unavoidable as it is the readily available and affordable energy source for developing economies like Nigeria. Noise is a by-product of the operations of package generators. The literature review has identified an array of damage that can be done to the ear as it does not have an overload switch or a circuit breaker. Consequent on the foregoing, the need for the control of noise exposure became an important and necessary requirement. Since it is not possible to control what you cannot measure, our control measure should therefore start with the evaluation of the associative noise level attached to the use of package generators. Literature review and discussions have revealed that noise control in package generators should begin with the "passive control" as a preferred option with emphasis on the option of absorbing the sound along its transmission path (that is at the muffler). The line of second defense should be the noise control through the "active control" options that should include noise cancellation Demo; modifying an active control headset and buying an off-the-shelf active control module. The third line of noise control should be the application of the Beam forming invention to reduce noise and Invention for the suppression of the quantization noise. The fourth and final line of noise control should be a total replacement alternative to the package generator such as the piezoelectricity and piezotronic effect of anatomically thin material molybdenum disulfide resulting in a unique electric generator. In order to minimize this associated noise with package generators, the design, testing and installation of the noise suppression unit (also known as the enhanced muffler) is a welcome development. Through this improvement, the efficiency and effectiveness of the package generator will be enhanced and this will elevate the overall health and wellbeing of the society.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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