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Industrial noise studies in quarries and neighbouring communities

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ABSTRACT

The study involved wide-range acoustical and social surveys in five quarries and two neighbouring communities. Results show that measured maximum noise levels, $L_{max.}$, were as high as 128 dB(A) at drilling blasting point 1 m away. Acoustical energy in the quarries even at low frequencies (32-63 Hz) are high (86.0-104.0 dB(A)) and between 90.0 and 106.0 dB(A) at 1-4 kHz where the normal ear is very sensitive. Noise levels at the facades of houses in the communities and schools and noise exposure levels range from 59.8 to 68.0 dB(A) and 53.0 to 70.2 dB(A) respectively, implying that only about 45% sentence intelligibility is achieved in the classrooms. Workers in the quarries have zero permissible occupational noise exposure time per day and percentage of overexposure per day that exceeds 33798. It is very worrisome that between 28.5 and 37.6% of the workers reported that they enjoy working in the quarries irrespective of the high noise levels.

Keywords: Industrial noise studies, quarries, neighbouring communities, noise levels and acoustical survey.

INTRODUCTION

Industrial (plant) noise levels, though not as high as the noise of aircraft during landing or take-off or as broadly distributed as those from highways, does not only affect turnover, profit margins, cause annoyance but cause permanent hearing damage to workers exposed to them each day and over a period of time. The noise, which varies depending on the level, source and characteristics, also affects communities close to the plants.

While Opitz (1968) commenced a discussion on the origin and treatment of noise produced by gears, Stewart *et al.* (1975) studied the parameters that influence punch press noise. Quinian (1999) looked at high frequency noise generated in small axial flow fans. Levels and characteristics of industrial noise as well as attitudes of industrial plant workers towards industrial noise have been investigated by a number of researchers (Menkiti,1994; Onuu *et al.*, 1996; Shaikh, 1996 and 1999; Onuu, 2002; Tawo,2003; and Akpan and Onuu, 2004).

Modern technology and discoveries which are a blessing and also a curse have led to the generation of many and varied sounds and noise that have given rise to the increase in the noise climate of the industries and the number of people with a disabling hearing impairment. The discovery of dynamite (nitroglycerin) by the Italian chemist, Asconio Sobrero in 1846, the invention of the blasting cap of a practical detonator by Nobel in 1865 and the use to which they are now put have added a new dimension to the problem of industrial noise pollution. The blasting cap which is a little capsule containing mercury fulminate that is inserted into a container of nitroglycerin and then ignited by a fuse can be used to blast mountains. This weapon of mass destruction and death (Awake, 2002) is now used in mining and quarrying to "blast" stones and rocks. Cranes and other machines are usually employed in loading stone, slate and other non-metallic solid mineral matter into tippers, trucks, lorries and other heavy vehicles. The result is that the environmental noise climate of the quarries (companies) and the neighbouring communities rises and the effects on humans, animals and structures also increase.

The objectives of this investigation are to conduct acoustical and social surveys involving sound levels and development of industrial noise characteristics at various locations in the quarrying companies, determination of response and attitude of the quarry workers. The effects of industrial noise on residents of the communities within the quarrying companies are also investigated. The quarries are Hi-Tech, Crushed Rocks in Old Netim, and Impresid, Astone and Stemco in Obung communities in Akamkpa Local Government Area, Cross River State, Nigeria.

THE QUARRIES SITES AND COMMUNITIES

The quarries where noise level measurements were made and social surveys conducted were Hi-Tech and Crushed Rocks located in Old Netim community and Impresid, Aston and Stemco located in Obung community. The quarries have incidence of high noise levels because of their activities. Measurement sites in the quarries and the communities were open and had level terrain. Houses of community

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residents and classrooms selected for the acoustical and social surveys were detached and faced the noise source. Old Netim and Obung communities are blessed with rich deposits of granite which has attracted the quarries that generate noise that affects workers and the neighbouring communities.

THEORY

The worker in the industry is frequently exposed to high levels of noise of different amounts during an 8-hour workday. Noise exposure rating, NER, gives a measure of the severity of industrial noise exposure and is calculated using the procedure published by the Committee on Hearing, Bioacoustics and Biomechanics, CHABA (1966) given by;

$$\text{NER} = \sum_i \frac{C_i}{T_i} \quad \ldots (1)$$

where: C_i is the total exposure time at a given steady noise level and T_i is the total exposure time at the corresponding noise level. If NER < 1, the noise exposure is considered acceptable, otherwise it is not.

Permissible occupational noise exposure time per day allowed under the limits 85, 88 and 90 dB(A) with exchange rate of 3 dB(A) has been given (Shaikh, 1999). Expression for percentage of overexposure per day of the maximum permissible limits of 90 and 85 dB(A) $L_{Aeq,}$ for 8 hour/day, both with exchange rate of 3 dB(A) has also been provided (Shaikh, 1999):

$$\% \text{ overexposure} = \left(\frac{\textit{Working schedule in h / day}}{\textit{Permissible exposure in h / day}} x100 \right) - 100 \quad \ldots (2)$$

Equation (2) can be computed using a working schedule of 8 h/day. Permissible exposure time (h/day) for the noise levels obtained in a plant for the limit of 90 dB(A) is got from Table 3 (Shaikh, 1999).

MATERIALS, METHOD AND ANALYSIS

Physical measurement

At a particular quarry, a preliminary noise survey was conducted to identify measurement locations and points. Measurements of industrial noise levels were made using the precision sound level meter (Bruel & Kjaer) Type 2203 with octave band filter (B & K) Type 1613. When the offensive noise source was identified in any particular quarry, measurements were then made at various points to determine the particular point with the highest noise level. During noise level measurements, the sound level meter was held in such a way that the microphone was, at least, 1m from any reflecting surface and 1.2m from the ground corresponding to the ear level of an average person. Several noise level measurements were made in a particular quarry to determine the maximum sound pressure level, $L_{max.}$. Using a stopwatch and the octave band filter, temporal noise characteristics and noise spectra were respectively plotted for each quarry. Similar procedures were followed and noise level measurements in the communities were made and recorded.

Social survey

Questionnaires were used for subjective assessment of the effects of industrial noise on the quarry workers, community residents and their attitude towards the former. A total of 1084 questionnaires (529 in Old Netim and 555 in Obung communities) were distributed and response rates of 85 and 88%, respectively, were recorded. The questionnaire comprised two main sections A and B. Section A contained information about the company/community while section B concerned the respondent. Information about age, length of service in the quarry, duty, previous noise exposure and hearing acuity was also contained in the questionnaire. Other questions included the following: How many hours do you work in this quarry in a day? In a week? What constitutes noise in your quarry? Do you like noise? The quarry workers were asked to rate noise in the quarry they work-in and to proffer solutions on the abatement and control of the quarry/industrial noise. Community residents contacted were asked the types of noise heard always and the most annoying noise if at all they were annoyed by it. Both the workers and community residents were asked the effect of noise on them. The questionnaire data were aggregated and analyzed for the quarries and the communities from which deductions were made.

RESULTS AND DISCUSSION

Physical measurement

Maximum noise levels, $L_{max.,}$ as high as 128 dB(A) were measured at drilling blasting points of the quarries at distance of 1.0 m from the source. Noise levels at various locations in the quarries and environ were also measured (Table 1). They vary from 51.2 to 69.0 dB(A) in the Project Managers' offices and from 107.4 to 109.6 dB(A) at the drilling blasting point where measurements were made at a distance of 2.0 m from the source. Temporal pattern of noise and noise spectra for the quarries are shown in Figs. 1 and 2 respectively. The noise levels are high and must therefore have associated physiological effects on the workers. Onuu *et al.* (1996) conducted a wide range of acoustical surveys of industrial noise in Calabar, Nigeria, and predicted associated pathological danger. Research on occupational noise induced hearing loss surveillance in Michigan, United States of America, has shown that a person's work performance and safety can be adversely affected by occupational noise- induced hearing loss (Mary *et al.*, 1998). The quarries, therefore, have hazardous noise levels. They do not have any hearing conservation programme (HCP) or measure put in place to protect workers from these high noise levels.

From Fig. 1 it is shown that Stemco generates the least noise which is 114 dB(A) followed by Impresid, Hi-Tech, Crushed Rocks

Table 1. Noise levels at various locations in the quarries and environ

Location	Noise levels (dB(A)
* Generator house	96.0 –99.0
* First crusher stage	92.0 – 98.5
Main gate	60.0 – 89.0
Office (inside)	69.0 – 85.0
Office (outside)	74.0 – 88.0
Nearest community house (at façade)	59.8 – 68.0
Primary School	53.0 – 70.2
Administrative managers' offices	50.4 – 56.5
Project managers' offices	51.2 – 69.0
*Drilling blasting point	107.4 – 109.6

* Measurements were made 2 metres from noise source.

and Astone, all of which generate the higher noise level of 128 dB(A) during the period. Clearly, the high noise levels at the quarries bode ill for the workers. Measured noise levels of 53.0 to 70.20 dB(A) in the Primary Schools suggest that sentence intelligibility of only about 45% will be achieved in the school (EPA, 1978). Noise levels in the quarries are high (Table 2) so that workers have zero permissible occupational noise exposure time per day, under the limit 90 dB(A) (Table 3). Each quarry generates noise levels greater than 115 dB(A) and so the percentage of over exposure per day of the workers exceeds the calculated value of 33798 using equation 2. This implies that workers are not supposed to work in any of the quarries.

Noise spectra for the quarries are similar (Fig. 2). Energy content per frequency is highest for Stemco throughout the octave band range of frequencies except at centre frequencies lying between 2 and 8 kHz where the energy content per frequency in other industries is higher. Worthy of note is the fact that acoustic energy in the quarries are high (86-104 dB(A)) even at low frequencies (32-63 Hz). The energy also ranges from 97.0 to 110 dB(A) and from 90.0 to 106.0 dB(A) between the frequencies of 1 and 4 kHz where the normal human ear is very sensitive. These levels are high enough to cause threshold shifts in the unprotected ears of workers.

Social survey

Table 2 shows working schedule for the staff of the quarries, which is 30-60 hours per week. It is unfortunate that workers are still exposed to industrial noise up to 60 hours per week (i.e. 12 hours per working day) despite the fact that noise levels in these quarries exceed 115 dB(A) which is the permissible occupational noise exposure level for 1 minute 25 seconds per day allowed (Table 3). Percentage age distribution of workers in the quarries is shown in Table 4. It is clear that majority of the workers in these quarries are between 16 and 45 years. Continuous exposure of the quarry workers to these high levels of noise will definitely accelerate their disabling hearing impairment. Some of the workers who are already victims thus add to millions of people in the world that are having this problem.

Responses of staff of the quarries constituted 60-75% for those in the range reporting that the quarries are noisy and extremely noisy; and about 25 and 40% for extremely quiet and quiet ratings respectively (Fig. 3). From Fig. 3 it is clear that staff of the quarries in Old Netim and community residents are disturbed more by noise of the quarries. This could partly be due to the very high noise levels generated by quarries in Old Netim. Further, 81.4% of workers in the quarries in Old Netim reported that they were annoyed by noise while less than half of this number (33.8%) reacted the same way in the quarries in Obung. In each case, noise rating (response) by staff of the quarries lies in the 60 – 75% of the total.

Rock blasting at the quarries in the communities is shown in Fig. 4. The peak blasting time for the quarries in both communities is 12 noon to 3p.m. while percentage blasting time for quarries in Old Netim/Obung communities are 4/8 (6-9a.m) and 4/7 (6p.m and beyond) respectively. This, therefore, suggests why a substantial percentage of the school children reported disruption of studies. Percentage blasting period by quarries in Obung communities exceeds

Table 2. Industrial noise levels in the quarries, working schedule, permissible exposure time and percentage of overexposure per day.

Quarry	L_{max} (dB(A))	A-Weighted SPL (dB (A)	Working schedule (h/week)	Permissible exposure time (h/day) hr mm sec.	*Permitted duration (hrs)	Percentage of overexposure per day
A. Old Netim						
1. Hi-Tech	122.0	120	30 – 60	0 00 00	0 (0)	>33798
2. Crushed Rock	118.0	113	30 – 60	0 00 00	0 (0)	>33798
B. Obung						
1. Impresid	122.0	118	30 – 60	0 00 00	0 (0)	>33798
2. Astone	128.5	125	30 -- 60	0 00 00	0 (0)	>33798
3. Stemco	117.0	112	30 -- 60	0 00 00	0 (0)	>33798

- Numbers in parentheses indicate the number of noise interval exposures for 8-h workday.

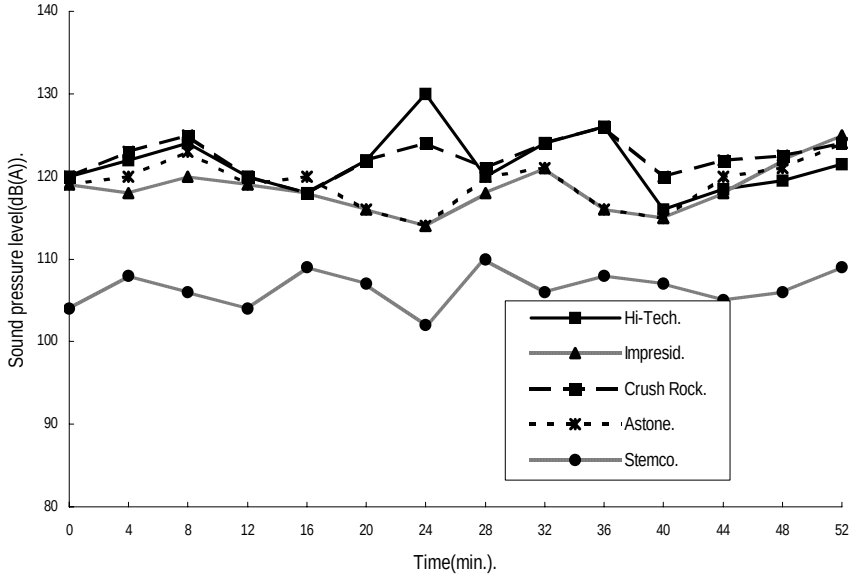

Fig. 1. Temporal pattern of noise level for the quarries

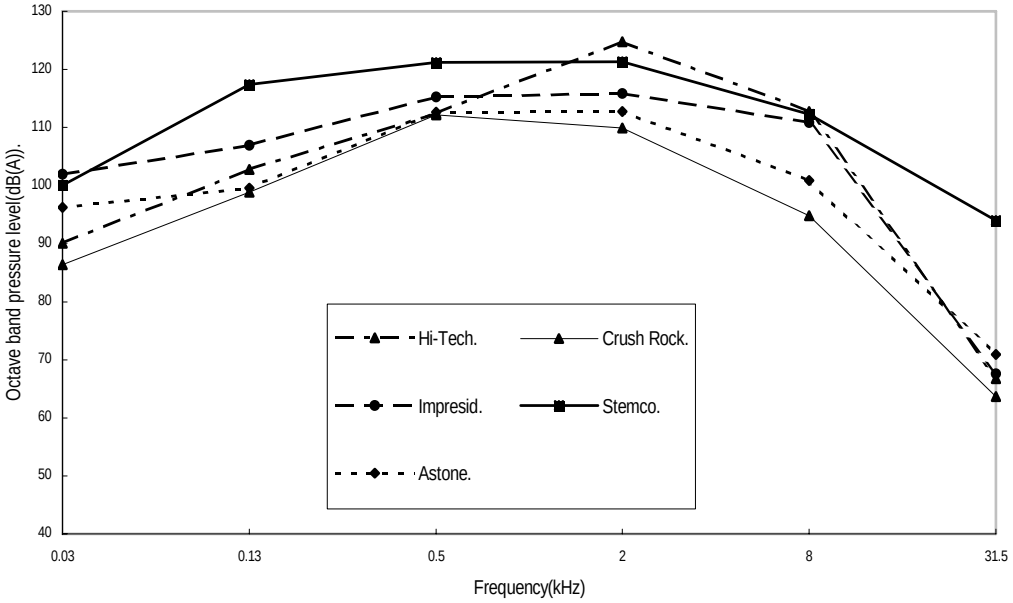

Fig. 2. Noise spectra for the quarries.

that of the quarries in Old Netim except at 12 noon to 3p.m. when that for the former is exceeded by 22. Fig. 4 will therefore be useful in noise abatement programmes for the communities. It is advised that schools, hospitals and other establishments cited in these communities should plan their activities outside the peak periods of activities of the quarries.

Effects of noise on workers in the quarries and community residents are shown in Fig. 5. Pupils in the class (25.0 – 44.7%) responded that they were disturbed while listening to their teachers. This has further confirmed our earlier assertion that less than 45% sentence intelligibility is achieved in the classrooms. Interference with conversation has percentage response of 13.4 – 20.4 while sleep disturbance by the noise has the least percentage response of 7.1 – 16.3. In each of these effects, community residents and workers dominated the lower and upper responses respectively.

On the attitude of the workers in the quarries to quarry noise, between 50.6 and 52.0% reported that they do not enjoy working because the quarries are noisy; 28.5 – 37.6% enjoy working irrespective of the high exposure noise levels while 11.8 – 19.5% enjoy working because the quarries, according to them, are quiet (Table 5). It is very worrisome that between 28.5 and 37.6% of the workers reported that they enjoy working in the quarries irrespective of the high noise levels they generate. This group of workers, perhaps, represents that category of people who see noise as a necessary consequence of urbanization and industrialization together with those who enjoy working because the quarries are quiet

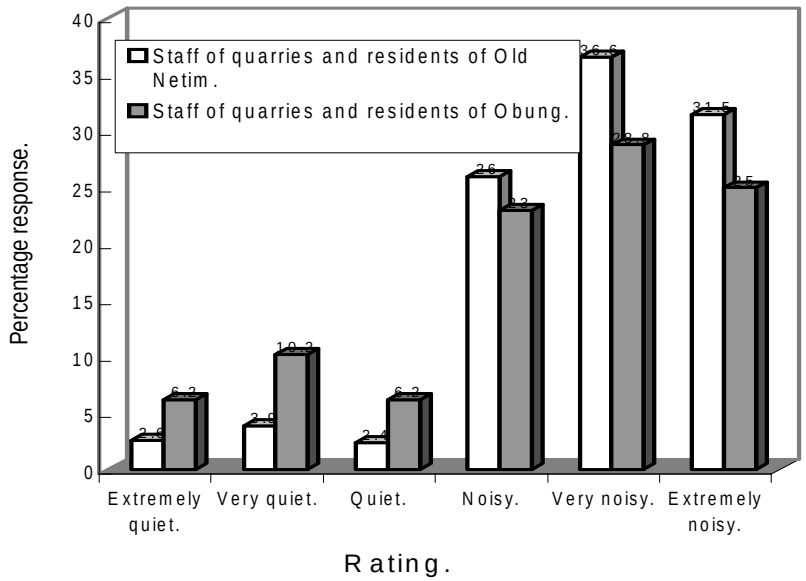

Fig. .3. Rating of noise by quarry staff and community residents.

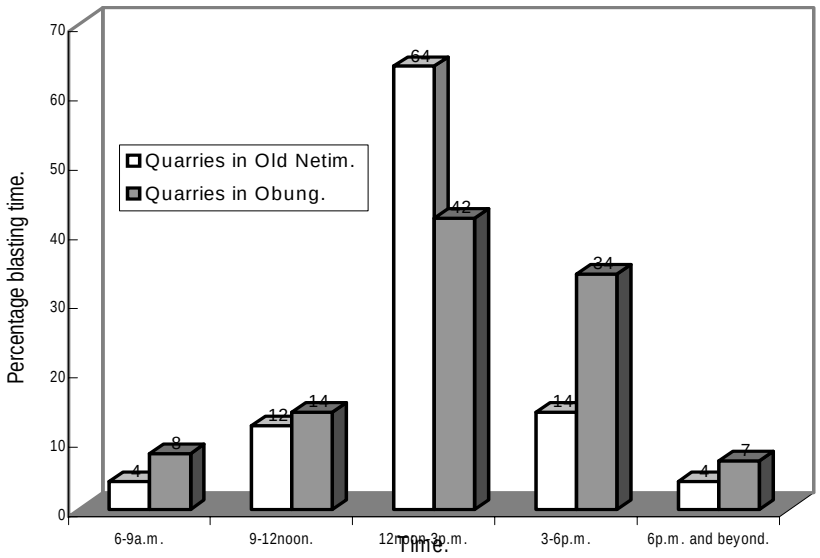

Fig. 4. Rock blasting by the quarries

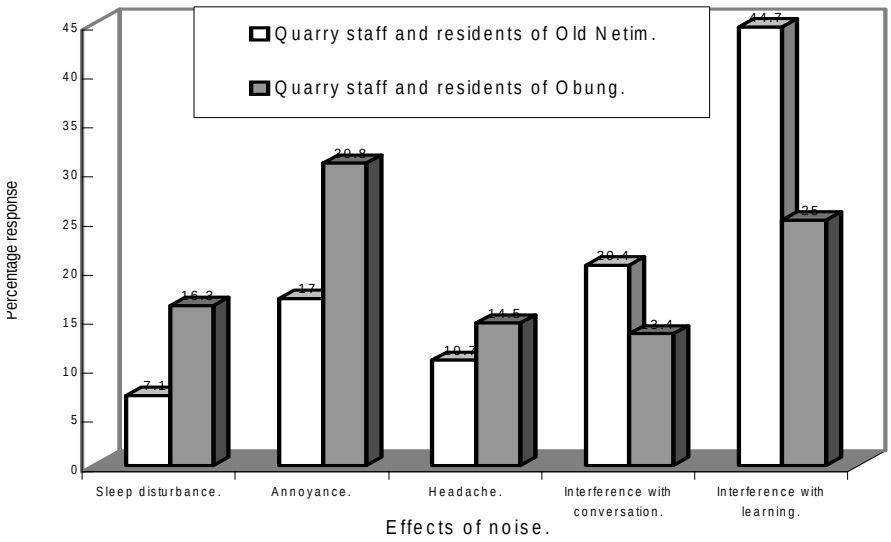

Fig. 5. Effects of noise on quarry staff and community residents.

Table 3. Permissible occupational noise exposure time per day allowed under the limit 90 dB(A) (Shaikh,1999).

Noise Level dB(A)	Occupational noise exposure time per day		
	hrs	min.	sec.
90	8	00	00
91	6	00	00
92	5	00	00
93	4	00	00
94	3	00	00
95	2	30	00
96	2	00	00
97	1	30	00
98	1	15	00
99	1	00	00
100	0	45	00
101	0	37	30
102	0	30	00
103	0	22	30
104	0	18	45
105	0	15	00
106	0	11	15
107	0	09	23
108	0	07	30
109	0	05	38
110	0	04	42
111	0	03	45
112	0	02	49
113	0	02	21
114	0	01	53
115	0	01	25

Table 4: Age distribution of workers in the quarries.

Age (years)	Percentage distribution
16 – 25	8.7 – 37.3
26 - 35	22.1 – 37.9
36 – 45	21.3 – 23.2
46 – 55	7.2 – 12.3
56 – 65	2.0 – 5.1
> 65	0.9 – 2.0

(11.8 – 19.5%). This group of "imperturbables" are definitely unaware of the irreversible effects of noise that are difficult to be controlled by physical means alone. From the social survey it was found that some workers in this group are suffering from hearing impairment.

RECOMMENDATIONS

The following recommendations are made for abatement and control of industrial noise at the quarries and communities.

i) Use of efficient noise barriers which can be erected around the quarries.

ii) Trucks and other road traffic in the categories of heavies should only be allowed into the quarries at specified periods of the day.

iii) Machines in the quarries should be maintained regularly.

iv) Management should organize seminars regularly for the workers to sensitize them on the ill effects of noise.

v) Workers should be encouraged to wear ear protective devices.

vi) Workers should be going for audiometry test from time to time.

vii) Schools in the communities should dismiss before 12 noon every day.

viii) People living near the quarries should be encouraged to move away.

ix) Management should pay compensation to the staff that are exposed to high noise levels.

x) Governments should ensure that existing anti noise laws and ordinances are enforced in the quarries.

Table 5. Summary of attitude of workers in quarries to noise.

Attitude	Percentage response
Enjoy working because the quarries are quiet	11.8 – 19.5
Do not enjoy working because the quarries are noisy	50.6 – 52.0
Enjoy working irrespective of the noise level	28.5 – 37.6

CONCLUSION

Industrial noise pollution is a serious environmental problem in these quarries and neighbouring communities where noise far exceeds recommended levels. Serious efforts should be made by both management and government to see that people work and live in such an environment free from hazardous noise levels.

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