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Occupational noise exposure for call-center workers

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ABSTRACT

For communication personnel, the occupational noise has to be determined in the ear canal as effect of sound immission from sources placed closed to the ear. This measurement could be carried out directly using miniature or probe microphones, or indirectly using a manikin equipped with ear simulators including microphones.

In both cases, special care should be addressed to experimental determination of the frequency-dependent transformation based on the gain exerted by the ear at different frequencies.

The investigation dealt with both measuring techniques. It has been undertaken in 74 different work stations (7 call centers) on 83 different types of receivers (supra-aural earphone, insert earphones, telephone handsets) for a 30 hour total monitoring time.

Results show that the noise exposure levels are extremely variable: from a minimum value of 50 dB(A) to a maximum value of 87 dB(A). Moreover, the level of 80 dB(A) is exceeded in 23% of cases.

By these data we can conclude that the risk of hearing loss could exist for some workers in certain conditions, as previously reported also by other researchers.

1 INTRODUCTION

In spite of rapid growth in the communications industry in the last century relatively little research has been published on occupational noise exposure for communication personnel. This lack of information has probably been due to the difficulties in the measurement set-up and in the assessment of the exposure itself. Moreover, telephone calls are typically verbal communications that, even if amplified, are considered a natural task and are not commonly associated to a hearing risk. Nevertheless, there is a high number of persons exposed to noise emitted from headsets (in Italy call centers are almost 2000 and call center workers are around 400000) and a high number of complaints are related to an over-exposition to this kind of noise.

Researches in this field have shown non uniform data. Experiments undertaken on telephone operators by Glorig et al. [1], Alexander et al. [2] and Juan et al. [3] tend to exclude a hearing loss risk connected to occupational noise exposure. On the contrary, a study undertaken by Chiusano et al. [4] on people continuously wearing a headset in a U.S.

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Department of Defence facility, by Ianniello [5] on telephone operators, by Dajani et al. [6] on telephone cable maintenance workers and airport ground crew, by Milhinch [7] on 100 call center operators and by Patel et al. [8] on 15 call centers (70 to 1450 operators each) show that this risk could actually exist. For Milhinch and Patel et al. sound levels adjusted by means of a transfer function are between 65 and 88 dB(A) and are higher than 80 dB(A) in 23% of cases. 8-hour exposure levels are between 67 and 87 dB(A) and are higher than 85 dB(A) only for a few operators (3 over 150) due to very high levels of the speaker's voice.

In the last decade, we have undertaken seven different experimental studies concerning workers wearing headphones [9]: in 74 different work places (7 call centers) on 83 different types of receivers (supra-aural earphone, insert earphones, telephone handsets) for a 30 hour total monitoring time. In this paper, a review of these studies is performed in order to have data as representative as possible.

2 LEGISLATION AND INTERNATIONAL STANDARDS

European Directive 2003/10/EC refers to the international standard ISO 1999:1990 for what concerns noise measurements and the definition of exposure level.

ISO 1999 establishes that the measurement of sound pressure to determine the sound exposure should be made with the microphone located at the position occupied by the head of the person concerned, the person being absent (I).

If it is necessary for the person to be present, the microphone should be located 0.10 m from the entrance of the ear canal of the ear receiving the higher value of sound exposure (II).

The Directive 1986/188/EC, previously in force, underlined the fact that in case I the worker should be absent in order to avoid any effect on the sound field; in case II the microphone should be located 0.10 m from the person's head in order to reduce, as far as possible, the effects of diffraction on the measured value. If the microphone must be located very close to the person's body (III), adequate modifications to the measured value should be undertaken in order to account for the field perturbation.

When dealing with communication headsets, the application of the first method is wrong. That is, noise measurements performed in the absence of the operator with the microphone closed to the headset does not take into account the strong coupling occurring between the sound source and the ear of the exposed worker. Nevertheless, the application of the second method is still absurd. That is, noise measurements performed 0.10 m outside the worker's ear are collected outside the headset too and give information of the environmental background noise rather than that emitted by the headset. Therefore, the application of the third method is the only one admitted and noise measurements must be performed very closed to the ear and must then be post-processed for adequate correction. In particular, for communication personnel the sound pressure value has to be detected within the area between the sound source and the ear; for example, at the cavum conchae or in the ear canal.

In this respect, a series of international standards (ISO 11904) have been drafted specifying methods for the determination of sound immission from sources placed closed to the ear. Part 1 of the series [10] describes measurements carried out using miniature or probe microphones inserted in the ears of human subjects (microphone in real ear – MIRE technique). Part 2 [11] describes measurements carried out using a manikin equipped with ear simulators including microphones (manikin technique).

By applying a frequency-dependent pressure transformation to the sound levels recorded within the ear (real ear for MIRE-technique and artificial ear for the manikin technique), typical sound pressure levels external to the ears that could have produced the internal measured values are recovered and can be used for comparison with accepted standards for assessing noise exposure. This frequency-dependent transformation is based on the gain exerted by the ear at different frequencies; that is, its frequency response. The resonance gain of the ear canal appears at 2500 Hz, while that of the concha comes out at 5-6 kHz. The gain level is around 10 dB [12,13].

3 EXPERIMENTAL STUDY

3.1 Occupational settings

The experimental stud y has been undertaken in seven different occupational settings:

1. a tape-recording division of a newspaper. In this site, the workers listen to articles dictated on the phone by outside locations and then double-check the articles while listening to their magnetic tape recordings. In the first part of their job the operators use telephone handsets with fixed gain but in the second part they wear supra-aural earphones with a variable gain.
2. telephone central office of a government organisation. In this site, the workers have to connect incoming calls to the right internal extension. The operators could use either telephone handsets with fixed gain or supra-aural earphones and insert earphones with a 3- level gain.
3. the same telephone central office as before, after the enlargement of the room. The operators have also new supra-aural earphones with adjustable gain, provided with a sound limiter.
4. bank call-center.
5. hospital call center.
6. joint call center for three companies (a bank, a local public administration and a service company).
7. call center of a national service company.

In the last four call centers, the workers answer to incoming telephone calls of their customers. The operators have supra-aural earphones with adjustable gain, provided with a sound limiter.

3.2 Measurement procedure and data processing

3.2.1 Manikin technique

The measurement protocol was simple. A commercially available Bruel & Kjaer 4128 head and torso simulator was used. It consists of a dummy head simulating the human head and external ear, with microphones located at the eardrums. The output from each microphone is a close approximation of the acoustic signal at the level of the median or average human ear exposed to a similar sound field. The output signals have been acquired by means of the Larson Davis 2900 dual-channel digital frequency analyser.

At each site, the manikin is positioned in the same environment as the listener, so that environmental sounds impinging on the listener and the manikin are as similar as possible.

For telephone installations provided by two output signals, two headsets of the same make and model are directly connected to them. In cases where a unique output signal is available, it is fed into a signal splitter that produces two output signals that are electrically independent and identical in shape and level to the original one. One headset is then worn by the operator and the other is fitted on the manikin’s head in a way that closely resembles the listener’s use.

Recordings are taken during normal working conditions including telephone conversations and temporary breaks in between. Short-time periods of 15-30 minutes are taken in medium or heavy communications traffic for a total recording time of 30 hours.

For each of the ear simulators integrated in the manikin, the sound pressure level is measured in one-third octave frequency bands. Then, each of the band levels is adjusted with the manikin diffuse-field frequency response to obtain corresponding diffuse-field related one-third octave band sound pressure levels. These levels are adjusted using A-weighting constants and subsequently combined to obtain the diffuse-field related equivalent continuous A-weighted sound pressure level. As an example, the effect of these frequency-dependent transformations is shown in figure 1 where the spectral adjustment has been applied to a noise measurement carried out at the bank call-center. Diffuse-field related equivalent continuous A-weighted sound pressure level is recovered for assessing noise exposure according to existing standards.

As to the frequency response, it is possible to choose between manufacturer's and standardised values [11], as well as between diffuse-field and frontally incident plane sound wave (free-field).

As shown in figure 2, these values differ from one another by 2-3 dB at most, except for frequencies above 6300 Hz where differences are higher. In any case, the latter frequencies are not relevant for our research because the telephone band-pass filter has a range of 300-3400 Hz.

In order to quantify how a tabulated frequency response is different from a specific one, an experimental investigation for the assessment of the frequency response of a manikin was undertaken in three different environments. In two cases, a dodecahedral sound source was chosen while in the third case the sound source was represented by the background noise of the workplace in which the measurements have been performed (hospital call-center). Results show that below 5000 Hz (300-3400 Hz is the frequency range most important for telephone conversations) the standardised frequency responses, the manikin manufacturer's ones and those measured with the same manikin in three different environments are quite similar and differ from one another only by 2-3 dB.

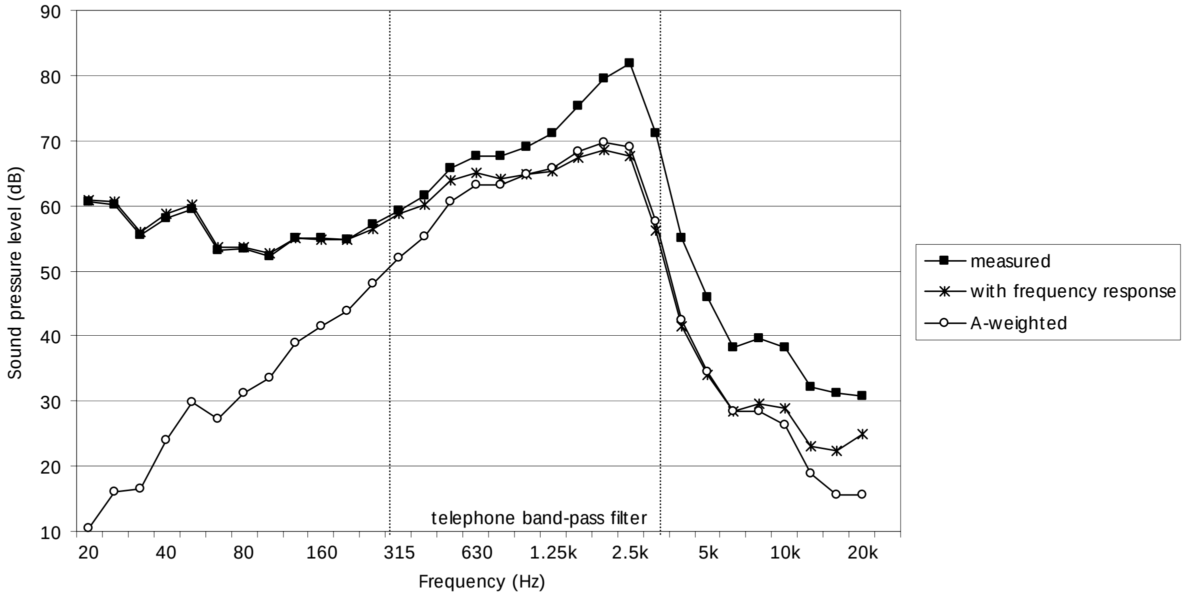

Figure 1: The effect of the frequency response and the A-weighting filter on a recording.

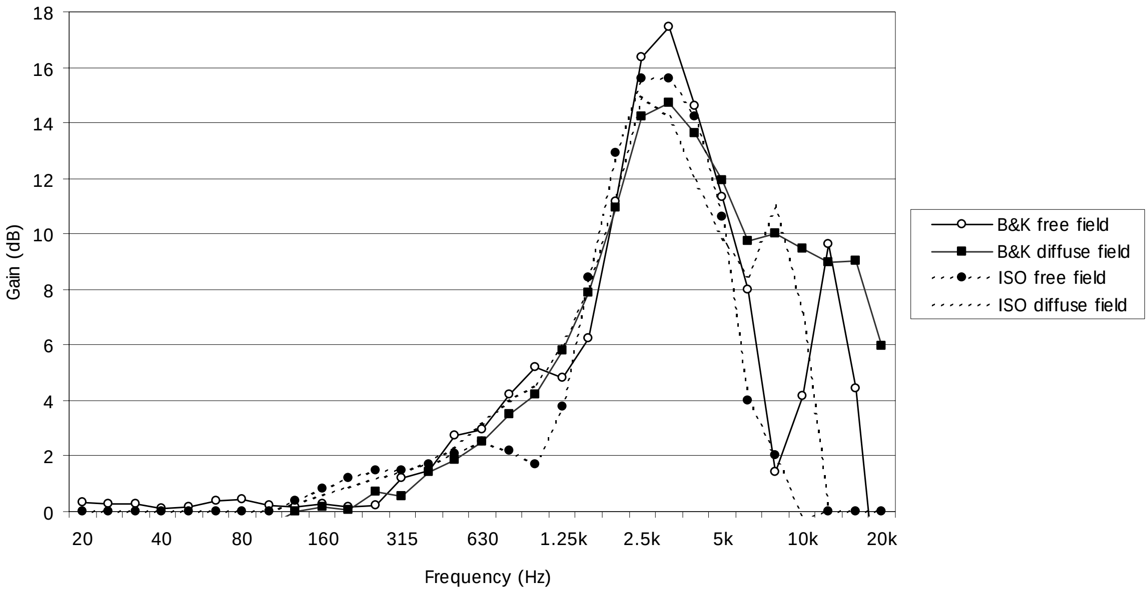

Figure 2: Manufacturer's and standardised values of free and diffuse field frequency responses.

3.2.2 MIRE technique

In the last occupational setting (call center of a national service company), simultaneously with the manikin measurement, a probe microphone B&K 4182 was used. This probe was provided by a flexible probe tube with external and internal diameters equal to 0.76 and 1.65 mm, respectively. The probe was connected to a power supplier B&K 5968, connected to a frequency analyser Larson Davis 2900. The probe tube was inserted in the operator's ear canal.

The frequency response for the probe microphone inserted in the ear canal was determined for each worker in a room closed to the call center office by means of a dodecahedral sound source emitting pink noise at 1.5 m for the worker. A microphone oriented toward the source was placed 0.10 m from the ear in which the probe was inserted. Immediately after the frequency response determination, the worker came back to his/her work with no modifications at all of the probe position. Then the worker wore the supra-aural earphone (earphone and probe do not interfere each others).

As to the frequency response of the small tube only (not inserted in the ear canal) the B&K UA 0922 was used. As shown in figure 3, for a 70 mm length probe tube (used for call center measurements), the frequency response differs by 2 dB at most in the frequency range of interest.

3.3 Sound level limiter

In the experimental study, particular attention has been addressed to the sound level limiter used in the telephone central office II. Its efficiency has been proved in laboratory by means of different sound signals generated with CoolEdit software and a suitable soundcard (Event Layla).

These test signals have been fed through the level limiter into the supra-aural earphone worn by the manikin. Then, the recordings made with the manikin have been analysed with the same software.

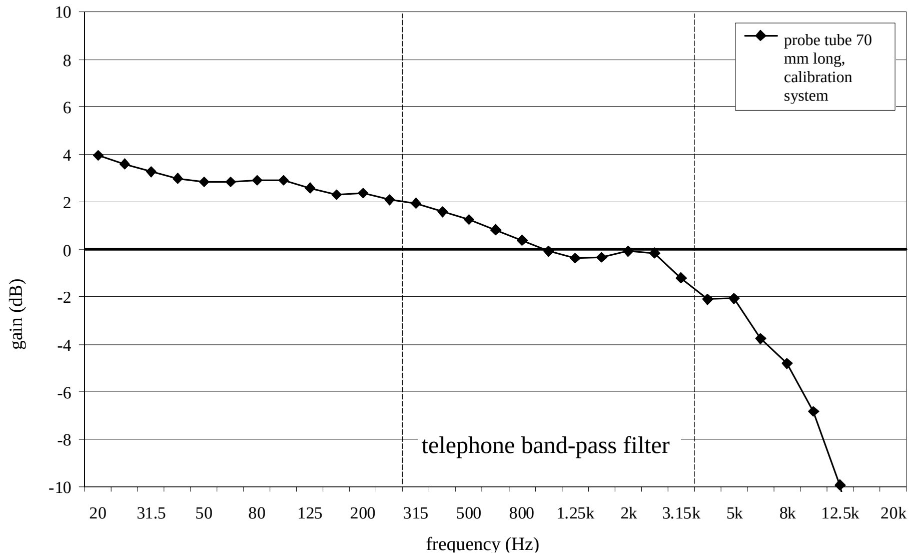

Figure 3: Frequency response for the probe tube 70 mm long by means of the B&K UA 0922 device

4 RESULTS AND DISCUSSION

4.1 General aspects

For communication personnel, noise exposure is affected by different factors here reported in descending order of importance:

- speakers' voice level. This factor depends on the speaker himself/herself and sometimes on the amplification level of the headset (there have been cases where the speaker's voice was 20-30 dB higher than the average value);

- workers' own voice. This effect (feedback echo) plays the operator's voice back into the headset, through the microphone of the device itself (in the bank call-center, the operator's voice level was higher than the speaker's one in 3 out of 11 cases and similar in 2 cases);

- background noise. This factor depends generally on the contemporary presence of a great number of operators working in the same place and could influence noise exposure either directly (as it could cross the shield offered by the supra-aural earphone) or indirectly (as a disturbance that induces the operator to raise the speaker's voice level).

4.2 Manikin technique

Table 1 reports the diffuse-field related equivalent continuous A-weighted sound pressure levels obtained with the manikin manufacturer's diffuse-field frequency response according to the procedure explained in paragraph 3.2.1. The diffuse-field frequency response has been selected because of the suggestions made up by Ianniello [5], Dajani et al. [6] and Brammer et al. [14].

The noise exposure levels reported in Table 1 are extremely variable: from a minimum value of 50 dB(A) to a maximum value of 87 dB(A). For all the measurements, 80 dB(A) is exceeded in 16 cases (11%) in the second occupational setting, in 4 cases (3%) in the sixth occupational setting and in 13 cases (9 %) in the seventh one. By these data we can conclude that the risk of hearing loss could exist for some workers in certain conditions.

The noise exposure levels have been calculated also with the manikin manufacturer's free-field frequency response and with the standardised free and diffuse field frequency responses reported in ISO 11904-2. For all the 148 recordings, the absolute value of the differences between the manufacturer's diffuse field related equivalent A-weighted level and the related equivalent Aweighted level obtained with the other three curves shown in figure 2 is always lower than 1.1 dB (the average difference is 0.5 dB). In conclusion, the differences shown in figure 2 have little effect on the noise exposure levels.

Table 1: Diffuse-field related equivalent continuous A-weighted sound pressure levels.

Occupational setting	Number of recordings	Number of workers and workplaces	Headset type	Amplification level	Sound pressure level dB(A)			
					mean	std. dev.	min	max
newspaper division	5	3	telephone handset	fixed	66.8	8.1	58.2	79.7
	6	1	Siemens handset	fixed	67.4	5.2	61.9	76.3
	17	3	supra-aural earphone	under the operator’s control	63.3	5.6	50.0	73.2
telephone central office I	6	3	telephone handset	fixed	76.6	1.7	74.4	79.0
	3	2	supra-aural earphone	level I	71.8	1.9	69.7	73.5
	6	4	supra-aural earphone	level II	77.8	1.7	75.9	80.7
	6	4	supra-aural earphone	level III	81.8	1.7	79.9	84.1
	3	2	insert earphone	level I	77.3	1.3	75.9	78.5
	6	4	insert earphone	level II	80.3	2.3	76.7	83.0
	6	4	insert earphone	level III	84.2	1.7	82.4	87.0
telephone central office II	8	3	supra-aural earphone with level limiter	level a	69.5	1.8	67.8	73.1
	6	2	supra-aural earphone with level limiter	level b	75.2	1.0	73.7	76.2
	6	2	supra-aural earphone with level limiter	level c	75.7	0.6	74.9	76.6
bank call-center	12	12	supra-aural earphone with level limiter	under the operator’s control	73.0	2.7	68.3	76.7
hospital call center	7	7	supra-aural earphone with level limiter	under the operator’s control	72.7	4.6	67.1	78.3
joint call center for three companies	9	9	supra-aural earphone Encore with level limiter	under the operator’s control	77.3	5.9	64.9	84.6
	9		supra-aural earphone Supra with level limiter	under the operator’s control	73.8	5.6	63.4	82.0
call center of a national service company	18	6	supra-aural earphone Encore with level limiter	under the operator’s control	76.0	5.1	67.6	82.6
	9	3	supra-aural earphone Supra with level limiter	under the operator’s control	78.9	6.2	70.7	86.6

4.3 MIRE technique

As already described, in the last occupational setting measurements have been simultaneously undertaken in the manikin’s ear and in the operator’s ear canal. For 3 operators the frequency responses obtained with the probe have shown a tendency similar to those determined in laboratory. These latter are reported in figure 4. The difference (absolute values) from the manikin measured values to the probe microphones measured values, adjusted with the adequate frequency responses, is at most equal to 1.7 dB (mean value 0.7 dB). This difference is therefore very small.

On the contrary, for other 6 operators the frequency responses obtained with the probe were different from that expected. The differences (absolute values) from the manikin to the probe microphones measured values, adjusted with the adequate frequency responses, are equal to 1-3 dB for 4 operators and equal to 15-20 dB for 2 operators. These anomalies can be caused by a wrong insertion of the probe tube in the operator’s ear canal and/or to ear wax occluding the ear. Such problems could be avoided by a otoscope exam before inserting the probe tube (in order to verify that the ear canal is not obstructed) and after that insertion (in order to verify the correct positioning of the probe tube).

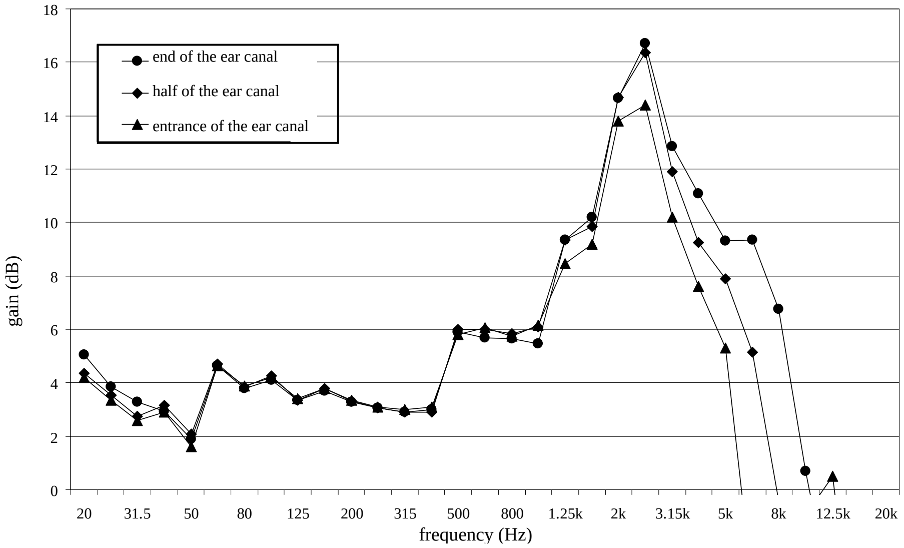

Figure 4: Frequency responses for the probe microphone in the ear canal, at different depths of insertion.

4.4 Sound level limiter

As to the sound level limiter, laboratory tests have shown a good evidence. If the input level were to exceed a defined threshold, for example 100 dB, the output level that is fed into the headset would be maintained under 100 dB in the first ms, reduced of 1-4 dB in the subsequent 10-15 ms, here maintained for 180 ms and then reduced of 9 dB in the subsequent 80-100 ms.

In conclusion, the output level never exceeds the defined threshold of 100 dB and provides a reduction of 10 dB (from 100 to 90) in 0.3 seconds.

5 CONCLUSIONS

Although the literature review does not show evidence of hearing loss for headset wearing communication workers and although some researchers tend to exclude a hearing loss risk connected to occupational noise exposure for call-center operators, more recently other researchers show that the risk could actually exist at least in certain conditions. The result of this experimental investigation confirm the latter consideration regarding the existence of risk. Therefore, the risk for call-center operators should be seriously assessed.

For exposure levels higher than 80 dB(A), the main causes should be detected in order to work out a specific programme of risk reduction.

In this respect, the efficiency of the sound level limiter should be verified. Moreover, authomatic telephone systems able to modulate the level input of the operators’earphones as a function of the speakers voice level. In any case, the call center operators should be adequately formed and informed.

As to the instrumentation, particularly interesting is the technique using microphone probes to be inserted into the operators ear canal (instead of manikin provided by artificial ear simulators). Microphone probes permit the measurement of the sound level directly in the specific operator's ear canal and permit also to perform measurements in the actual working conditions, that is with the earphone positioned by the operator himself/herself on his/her ears.

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