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Differences in the performance of metal- and plastic-cased TDH-39 and TDH-49 audiometric earphones, and consequences for their calibration

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ABSTRACT

Since the Telephonics type TDH-39 gained its position as one of the main audiometric earphones in use in Britain, there have been several superficial changes to its design, the most significant of which was the change from a metal to a plastic cased version, the TDH-39P. It was assumed at the time that the new plastic cased version was equivalent to the original metal cased version as both types exhibited similar frequency responses when measured using the IEC 303 acoustic reference coupler.

Canning (1991) conducted an investigation into the two types of TDH-39 using data compiled from his own audiometer calibrations. Transfer sound pressure level (SPL) values, ie. the difference between the sound pressure levels generated by an earphone when measured using the IEC 303 acoustic reference coupler and the IEC 318 artificial ear, were calculated for both earphone types, and he concluded that the two types of earphone exhibited significant differences at 6 kHz.

The object of the work reported here was to investigate further the metal and plastic cased TDH-39 and quantify any differences between them. On examining various earphones it was discovered that the original metal cased TDH-49 had also been superseded by a plastic cased version, the TDH-49P, and these earphone types were also included in the investigation. Five samples of each earphone type were measured on two IEC 303 acoustic reference couplers and two IEC 318 artificial ears. The transfer SPLs were used to assess the differences between the earphone types.

Our results for the type TDH-39 and TDH-39P earphones verify Canning's results, with a difference in transfer values of the order of 5 dB at 6 kHz. The TDH-49 and TDH-49P earphones do not exhibit such large differences in transfer values, the difference being of the order of 3 dB at 6 kHz. Differences of the order of 2 dB were observed over the range 3 - 4 kHz for both TDH-39/39P and TDH-49/49P earphones. It is concluded that a move away from the use of TDH39/39P earphones for audiometry would be beneficial both to avoid this problem of differing performance and to facilitate the adoption of the IEC 318 artificial ear as the sole calibration device for supra-aural audiometric earphones.

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CONTENTS

1 INTRODUCTION

A pure tone air conduction audiometer is used to measure a person's threshold of hearing as a function of frequency relative to a set of reference equivalent threshold sound pressure levels (RETSPLs). These reference levels are defined internationally in ISO 389:1991[1] (BS 2497:1992[2]), in terms of the sound pressure set up by a supra-aural audiometric earphone when coupled to a standard device which simulates the human ear. The earphone is calibrated using an acoustic reference coupler (IEC 303:1970[3], BS 4668:1971[4]) or an artificial ear (IEC 318:1970[5], BS 4669:1971[6]), depending on the earphone type.

Since the Telephonics type TDH-39 gained its position as one of the main audiometric earphones in use in Britain, there have been several superficial changes to its design. In 1963 the filter cloth in the earphone was changed but matched to produce the same earphone response on the American NBS 9A coupler, and during this change about 1000 devices were manufactured with unmatched cloth[1,2]. However the most significant change was from a metal to a plastic cased version - the Telephonics type TDH-39P. It was assumed at the time that the new plastic cased version was equivalent to the original metal cased version as both devices supposedly exhibited similar frequency responses when calibrated using the IEC 303 acoustic reference coupler. Following this the earphone cushion was changed from a two piece (MX 41/AR) to a one piece (Model 51) design, but only the MX 41/AR cushion was explicitly mentioned in the relevant standard of the time (ISO 389:1985[7], BS 2497:1988 Part 5[8]) and confusion existed as to whether the acoustic reference coupler or the artificial ear should be used for the TDH-39P earphone fitted with the Model 51 cushion.

Canning[9] (formerly RNID now EMIS, Glasgow) carried out a study using data compiled from audiometer calibrations and concluded that TDH-39 and TDH-39P earphones were not in fact equivalent. It was therefore decided to evaluate, using a controlled and systematic approach, the frequency response characteristics for TDH-39 and TDH-39P earphones. On examining various earphones it was also discovered that the original metal cased TDH-49 earphone had been superseded by a plastic cased TDH-49P, and various unmarked cushions were being used with it. Since no comparison had been made to date it was decided to extend the study to include TDH-49 and TDH-49P earphones.

Samples of each of the four earphone types were calibrated on two IEC 303 acoustic reference couplers and two IEC 318 artificial ears and the results are presented here along with a comparison with results obtained by Robinson[10,11] and Canning[9].

2 BACKGROUND

Problems with the calibration of Telephonics TDH-39 earphones have been reported as far back as 1964. Rudmose[12] discussed problems encountered when calibrating TDH-39 earphones with the NBS 9A coupler (equivalent to the IEC 303 acoustic reference coupler) and the ASA type 1 coupler. This earphone type exhibited a strong peak in its frequency response characteristic in the vicinity of 6 kHz but did not perform in the same manner when coupled to the human ear.

Howard[13] compared the frequency response characteristics of TDH-39 and TDH-49 earphones measured using two types of American standard coupler (the NBS 9A and the ASA type 1 coupler) with the pressure response produced in the human ear. For the TDH-39 earphone, the causes of the dip at 2 kHz and the peaks at 4 kHz and around 5.5 kHz were explained, the peak around 5.5 kHz being caused by an interaction between the coupler and the earphone. Howard also discussed how this information was used in the design of the TDH-49 which has more built-in damping and a flatter smoother frequency response to higher frequencies.

Robinson[10] collated the frequency response characteristics of a number of TDH-39 earphones in terms of their transfer sound pressure level (SPL) values, ie. the difference between the sound pressure levels generated by an earphone on the IEC 303 acoustic reference coupler and the IEC 318 artificial ear. Along with data for several other earphones types (most of which are now obsolete) these data were used to enable reference equivalent threshold sound pressure levels (RETSPLs) to be calculated for the IEC 318 artificial ear. In his report, Robinson noted considerable intra-type variability at 6 kHz for the TDH-39. Transfer SPL values for TDH-49 earphones were also reported.

Robinson, Shipton and Hinchcliffe[11] carried out work to determine the normal threshold of hearing. In the process they measured transfer SPL values for a further group of TDH-39 earphones, and the data were found to be particularly variable at 6 kHz.

Sherwood and Shipton[14] investigated two non-standard configurations for the IEC 303 acoustic reference coupler in which a Brüel and Kjær type DD 0011 or type DD 0015 protective grid is used to protect the microphone diaphragm. It was found that the use of protective grids can cause errors at high frequencies, with discrepancies of 3 dB at 6 kHz when using the Western Electric style DD 0015 grid. The problem of protecting the microphone diaphragm does not arise when using the IEC 318 artificial ear because the microphone is required to be used with its protective grid in place.

Canning[9] compared transfer sound pressure level (SPL) values - the difference between the sound pressure levels generated by an earphone on the IEC 303 acoustic reference coupler and the IEC 318 artificial ear - for groups of TDH-39 and TDH-39P earphones. His results indicated a difference in average transfer SPL value at 6 kHz of approximately 10 dB between the two earphone types, casting doubt as to whether the plastic-cased Telephonics TDH-39P earphones now widely in use are truly equivalent to the old metal-cased TDH-39 earphones for which the IEC 303 acoustic reference coupler is specified as the appropriate calibration device. This also raised questions about the similarity that was assumed to exist between the TDH-49 and the newer plastic cased TDH-49P earphones.

RETSPL values for the IEC 303 acoustic reference coupler and the IEC 318 artificial ear were published in ISO 389:1985[7] and its two Addenda[15,16] which were identical to BS 2497:1988 parts 5[8], 6[17] and 7[18]. BS 2497:1988 Part 5[8] specifically stated that the RETSPLs in the standard applied only to a TDH-39 earphone with MX 41/AR cushion or a Beyer DT48 earphone with flat cushion calibrated on an IEC 303 acoustic reference coupler. This implied that if a TDH-39 earphone was fitted with the new style Model 51 cushion it should be calibrated using an IEC 318 artificial ear together with the RETSPLs for that device.

NPL carried out an investigation into the equivalence of the MX 41/AR and Model 51 cushions. Dowson, McNeill and Torr[19] concluded that the cushion types can be taken as identical when fitted to TDH-39 earphones mounted on an IEC 303 reference coupler, except at 6 kHz where differences in earphone sensitivity of up to 2.8 dB were observed. There was an indication that the difference at 6 kHz was dependent on whether the earphone was metal or plastic cased. These results were consistent with those of Michael and Bienvenue[20] except at 2 kHz where the latter authors found a difference of around 1 dB between the two earphone cushion types.

ISO decided to revise the standard and clarify any ambiguity by defining the cushions as equivalent in ISO 389:1991[1] (published also as BS 2497:1992[2]). BS 2497:1992 now states that the IEC 303 acoustic reference coupler should only be used with Beyer DT48 earphones with flat cushions and with Telephonics TDH-39 earphones fitted either with MX 41/AR cushions or with the newer style one-piece Model 51 (P/N 510C017-1) cushions, when the RETSPLs given in BS 2497[2] Table 1 should be used. The IEC 318 artificial ear and RETSPLs given in BS 2497[2] Table 2 should be used for any other combination within specified limits. Although the MX 41/AR and Model 51 cushions are stated as equivalent, no mention is made of the supposed equivalence of metal and plastic cased earphones.

It was therefore decided to carry out a further investigation using a controlled and systematic approach, to measure the frequency response characteristics and compare the transfer SPL values for Telephonics TDH-39 and TDH-39P earphones, and compare these with previous results. The study was also extended to include TDH-49 and TDH-49P earphones.

To complete the background, Table 1 summarises the current British Standards (BS) and their International Electrotechnical Commission (IEC) and International Organization for Standardization (ISO) equivalents which are relevant to the calibration of audiometric earphones.

Table 1 Current Standards relating to calibration of audiometric earphones

British Standards	IEC Publications	ISO Standards	Description
BS 2497:1992[2]		ISO 389:1991[1]	Reference zero for the calibration of pure tone audiometers
BS 4668:1971[4]	IEC 303:1970[3]		Acoustic coupler for the calibration of audiometric earphones
BS 4669:1971[6]	IEC 318:1970[5]		Artificial ear for the calibration of audiometric earphones

3 MEASUREMENT METHOD

3.1 MEASUREMENT SYSTEMS AND THEIR CALIBRATION

Two acoustic reference coupler systems and two artificial ear systems were used for the measurements (Figure 1). Each acoustic reference coupler system consisted of a one inch pressure microphone (Brüel and Kjær type 4144) with adaptor ring (Brüel and Kjær type DB 0111) fitted, an IEC 303 acoustic reference coupler (Brüel and Kjær type 4152), connecting lead and adaptors, an IEC type 1 sound level meter (Brüel and Kjær type 2235) and a filter set (Brüel and Kjær type 1625). Each artificial ear system consisted of a half inch pressure microphone (Brüel and Kjær type 4134) with slotted grid fitted, an IEC 318 artificial ear (Brüel and Kjær type 4153), connecting lead and adaptors, an IEC type 1 sound level meter (Brüel and Kjær type 2235) and a filter set (Brüel and Kjær type 1625).

In fact only two sound level meters with attached filter sets were used for the measurements, each meter being used as part of one acoustic reference coupler system and one artificial ear system. A calibrated sound calibrator (Brüel and Kjær type 4220) was used to make the initial sensitivity adjustment of each system and to check that the systems maintained their calibrations during the course of the investigation. All calibrations and measurements were carried out in a temperature controlled room held at 23 ± 1 °C. The serial numbers of the four measurement systems are listed in Appendix 1.

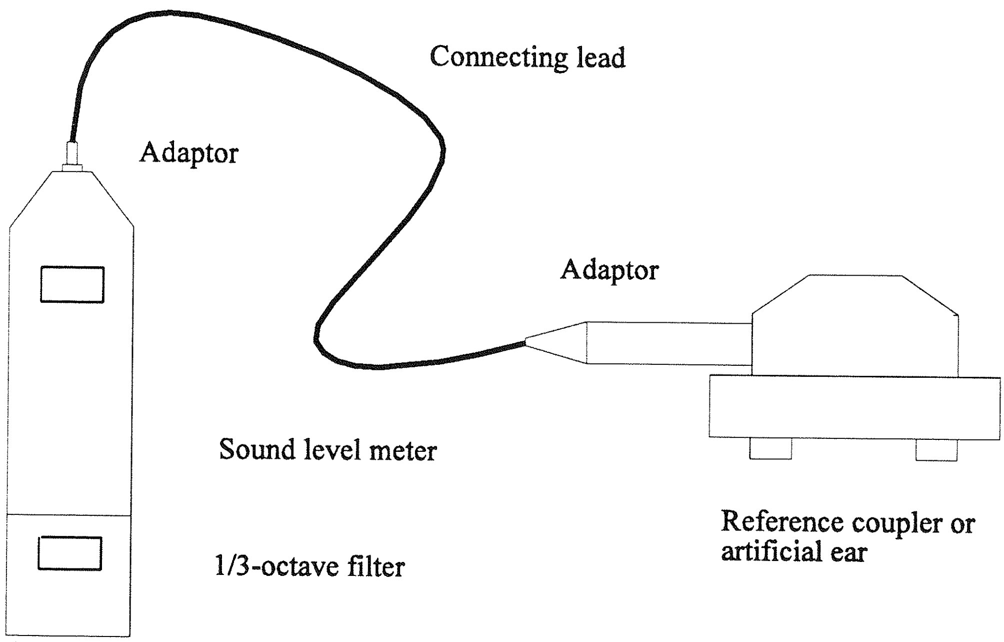

Figure 1 Measurement systems

Each system was calibrated by the substitution method, using a standard calibrated one-inch microphone as reference. The principle of the calibration was as follows. The cylindrical body of the acoustic reference coupler or artificial ear was unscrewed and removed, and the microphone of the system was coupled to a one-inch transmitter microphone using a standard air filled microphone coupler (Brüel and Kjær type DB 1392). A level of 74 dB as indicated by the system was then set up in the microphone coupler using the transmitter. The test system was then replaced by the standard microphone and the true sound pressure level in the coupler was measured using the insert voltage technique. For the artificial ear systems, it was necessary to adapt the half inch microphones so that they had the same geometric shape as a one-inch microphone. This was achieved by unscrewing the grids and replacing them with adaptor rings (Brüel and Kjær type WA 0220/WA 0221).

From these measurements, and by applying corrections for the difference in the front volumes of the test and standard microphones and other effects in the microphone couplers, the responses of the four test systems were calculated. The calibrations were carried out at the preferred third octave frequencies and common audiometric test frequencies between 125 Hz and 8 kHz as specified in ISO 389:1991[1]. For each system, the filter set was switched to the third octave centre frequency closest to the test frequency. The overall uncertainty in the calibration of the acoustic reference coupler or artificial ear systems was estimated to be 0.16 dB for a confidence probability of not less than 95%.

3.2 SELECTION OF EARPHONES

Five earphones of each of the four types (Telephonics TDH-39, TDH-39P, TDH-49 and TDH-49P) were selected. All were of low impedance, nominally 10 Ω (TDH-39 earphones have also been produced in a high impedance - 100 Ω - version, but these were not used). Initially all of the earphones were inspected to ensure that there were no signs of damage. The cushions were also inspected, replaced if they had degraded and the cushion type fitted to each earphone was recorded and is shown in Table 2.

Table 2 Serial number of earphones and cushion type fitted

Earphone type	Sample number				
	1	2	3	4	5
TDH-39	89140 with MX 41/AR	A75A with Model 51	A75B with Model 51	A75C with Model 51	A75L with Model 51
TDH-39P	A140600 with MX 41/AR	076318 with Model 51	076330 with Model 51	36878 with Model 51	A107480 with MX 41/AR
TDH-49	No. 1 with MX 41/AR	No. 2 with MX 41/AR	No. 2A with MX 41/AR	No. 2B with MX 41/AR	No. 8 with MX 41/AR
TDH-49P	A814537 with MX 41/AR	A41332 with Model 51	A41281 with MX 41/AR	A41308 with Model 51	A41283 with MX 41/AR

The frequency response characteristic was measured for each of the earphones, and the earphones were also checked audibly using pure tones and broad band signals. Those that had a distorted output were rejected and replaced.

3.3 MEASUREMENT PROCEDURE

Each measurement system was set up and each earphone in turn was coupled to the acoustic reference coupler or artificial ear with a static force of 4.5 N (excluding the weight of the earphone). This force was supplied by a brass cylindrical mass mounted on the earphone. The earphone was driven by a voltage of 100.0 ± 0.4 mV r.m.s. applied across the earphone terminals at each of the preferred third octave frequencies and common audiometric test frequencies between 125 Hz and 8 kHz. Using the third octave filter closest to the excitation frequency, the sound level meter reading was recorded.

Measurements were made in sets of five for each earphone on each of the four couplers, the earphone being rotated by 120° for each measurement. Thus data were accumulated on five repeated measurements, on each of five earphones, of each of four earphone types, on each of four measurement systems.

4 ANALYSIS OF RESULTS

4.1 FREQUENCY RESPONSE CHARACTERISTICS

From the five measurements made at each frequency, for each earphone/measurement system combination, the mean sound level meter reading was calculated. Knowing the calibration results for each of the acoustic reference coupler and artificial ear systems, corrections were applied to the mean sound level meter readings and the corresponding mean sound pressure levels were calculated. Figures 2 and 3 respectively show five TDH-39P earphones measured on one acoustic reference coupler and five TDH-49P earphones measured on one artificial ear.

Results for the five earphones of each type were then combined to give the overall mean frequency responses for each of the four earphone types measured on each of the four measurement systems. Results for each earphone type measured on the two acoustic reference couplers were then compared, and likewise for the two artificial ears. Figures 4 and 5 show the overall mean frequency responses of the TDH-39 and TDH-39P earphones measured on each of the two acoustic reference couplers, while Figures 6 and 7 show the overall mean frequency responses of the TDH-49 and TDH-49P earphones measured on each of the two artificial ears.

Finally, results for the two acoustic reference couplers were combined to produce grand mean frequency responses for each of the four earphone types on that coupler type, and likewise for the two artificial ears. Figures 8 and 9 compare respectively the grand mean frequency response characteristics for the TDH-39 and TDH-39P earphones measured on the acoustic reference coupler and the TDH-49 and TDH-49P earphones measured on the artificial ear. Likewise, Figures 10 and 11 compare respectively the TDH-39 and TDH-39P earphones measured on the artificial ear and the TDH-49 and TDH-49P earphones measured on the acoustic reference coupler, though as explained in Section 2, these earphone/measurement system combinations are actually not permitted for calibration purposes.

4.2 TRANSFER SPL VALUES

Going back to the mean sound pressure levels calculated for each earphone/measurement system combination, the transfer SPL values for each earphone were calculated from:

$$\textbf{Transfer SPL value} = \mathbf{L}_{318} - \mathbf{L}_{303}$$

where $\mathbf{L}_{318}$ is the mean sound pressure level averaged over the two IEC 318 artificial ears, and $\mathbf{L}_{308}$ is the mean sound pressure level averaged over the two IEC 308 acoustic reference couplers. Figures 12 and 13 show respectively the transfer SPL values for the TDH-39 and TDH-39P earphones, and the TDH-49 and TDH-49P earphones, averaged over the five specimens of each type. Robinson's data for the TDH-39 and TDH-49 earphones are also included in these figures.

4.3 COMPARISON WITH OTHER DATA

Transfer SPL values at 6 kHz for the TDH-39 earphone were compared with results obtained by Robinson[10,11] and by Canning[9]. The relevant means and associated standard deviations are shown in Table 3.

Table 3 Comparison of mean transfer SPL values at 6 kHz for TDH-39 earphones.

Source	Sample	Mean transfer SPL value	Standard deviation
Robinson[10] (1978)	26	4.8 dB	3.4 dB
Robinson et al.[11] (1979)	8	4.7 dB	2.4 dB
Canning[9] (1991)	12	2.9 dB	4.7 dB
This report	5	0.1 dB	1.8 dB

Canning also calculated transfer SPL values at 6 kHz for a large sample of TDH-39P earphones and the resulting means, and associated standard deviations are shown in Table 4.

Table 4 Comparison of mean transfer SPL values at 6 kHz for TDH-39P earphones.

Source	Sample	Mean transfer SPL value	Standard deviation
Canning[9] (1991)	53	-6.8 dB	2.1 dB
This report	5	-5.2 dB	2.0 dB

Finally, Table 5 shows comparative results at 6 kHz for the TDH-49 earphone, derived from Robinson[10] and this report.

Table 5 Comparison of mean transfer SPL values at 6 kHz for TDH-49 earphones

Source	Sample	Mean transfer SPL value	Standard deviation
Robinson[10] (1978)	5	4.5 dB	1.4 dB
This report	5	2.7 dB	1.3 dB

These comparative data are discussed in the next section.

5 DISCUSSION

The five repeated determinations of the response of any one earphone on any one coupler produced standard deviations of typically 0.05 dB though in some cases at high frequencies this increased to as much as 0.2 dB .

Figures 2 and 3 show the frequency responses of five TDH-39P earphones measured on one reference coupler and five TDH-49P earphones measured on one artificial ear. At low frequencies, the sensitivities of the five samples of each earphone type lie within a span of about 0.8 dB, demonstrating the close manufacturing tolerances on these earphones. For the TDH-49P earphones measured on the artificial ear, this close control extends up to a frequency of 3 kHz, at which point the response of one of the five samples starts to deviate from the rest. However, the responses of the remaining four samples remain remarkably close.

Figures 4 to 7 show the overall mean frequency responses of each of the four earphone types measured on the appropriate acoustic reference coupler/artificial ear systems. It can be seen that the results from the two acoustic reference coupler systems are very close, and likewise for the two artificial ear systems. For the two acoustic reference coupler systems, agreement is within 0.5 dB, except at 8 kHz where it deteriorates to 1.5 dB. For the two artificial ear systems, it is within 0.5 dB across the entire frequency range. However, this is not to suggest that the artificial ear is "better", since only two samples of each device were used.

Figure 8 shows the grand mean frequency responses of the TDH-39 and TDH-39P earphones measured on the acoustic reference coupler. It can be seen that at frequencies below 2 kHz the sensitivities are very similar, being within 1 dB, and moreover the curves are parallel. At higher frequencies the responses diverge, and at frequencies between 3 kHz and 6 kHz the shapes of the curves are significantly different. In particular, the response of the TDH-39 shows stronger peaks at 3.15 kHz and between 5 kHz and 6 kHz than does the response of the TDH-39P. At 6 kHz, the difference between the responses attains 4.7 dB.

Figure 9 shows the grand mean frequency responses of the TDH-49 and TDH-49P earphones measured on the artificial ear. At low frequencies the response curves are less flat than for the TDH-39 and TDH-39P (though it should remembered that the measuring device is different). Nevertheless, the sensitivities of the TDH-49 and TDH-49P are within about 1 dB at frequencies below 2 kHz. At higher frequencies the curves diverge significantly, though less so than in Figure 8. Only one peak is present, at 3.15 kHz, and this is more pronounced for the TDH-49P than for the TDH-49. The maximum difference between the responses is 3.2 dB, at 3.15 kHz.

Figures 10 and 11 show respectively the responses of the TDH-39 and TDH-39P earphones measured on the artificial ear, and those of the TDH-49 and TDH-49P earphones measured on the acoustic reference coupler. Although it is incorrect to use these earphone/measurement system combinations, the results in these figures help to distinguish those features of Figures 8 and 9 which are functions of the earphone type from those which are functions of the measuring device. Comparing Figures 8 and 10, the relative sensitivities of the TDH-39 and TDH-39P earphones are the same at frequencies up to 2.5 kHz, whether measured on the acoustic reference coupler or the artificial ear. However, at higher frequencies there are differences, dependent on the measuring device. The same is true of the relative sensitivities of the TDH-49 and TDH-49P earphones, displayed in Figures 9 and 11. Nevertheless, the distinctive increase in sensitivity at frequencies up to 400 Hz seen in Figures 9 and 10 is seen to be a function of the artificial ear. Finally, it would appear from Figure 11 that the TDH-49 and TDH-49P were designed to have a flat frequency response when measured on the acoustic reference coupler, even though according to ISO 389[1] this is the incorrect calibration device.

Figure 12 compares mean transfer SPL values for the TDH-39 and TDH-39P earphones. Included are Robinson's data for the TDH-39 taken from Reference 10. The TDH-39 and TDH-39P are indistinguishable at frequencies up to 2.5 kHz, and agreement with Robinson's data is excellent up to 4 kHz. At higher frequencies the transfer SPL values for the TDH-39 and TDH-39P vary rapidly with frequency and diverge significantly, and the agreement with Robinson's data for the TDH-39 is rather poor.

Figure 13 compares similar data for the TDH-49 and TDH-49P earphones. Again, the two earphone types are indistinguishable at frequencies up to 2.5 kHz, and agreement with Robinson's data is excellent up to 4 kHz. The variation and divergence of the transfer SPL values at higher frequencies is less pronounced than in Figure 12, and the agreement with Robinson's data is also better.

Table 3 compares transfer SPL values for the TDH-39 earphone in greater detail at 6 kHz; this is the frequency on which Canning focused. The variability of the results in this report, as revealed by the standard deviation of the measured transfer SPLs, is less than for Robinson's and Canning's results. Robinson's results differ significantly from those in this report, but Canning's results fall midway and could be taken to agree with either. Given that the agreement with Robinson is so good at lower frequencies, instrumental differences can probably be ruled out. It may well be that the batches of earphones tested by Robinson, Canning and ourselves have genuine differences at high frequencies.

Table 4 compares Canning's data for the TDH-39P earphone with data from this study. For this earphone type, there is no significant statistical difference (at the 5% level) between the mean transfer SPL values. Nevertheless, it is clear from Canning's results and this study that there is a systematic difference of the order of 5 to 10 dB at 6 kHz between the transfer SPL values for TDH-39 and TDH-39P earphones.

Table 5 compares Robinson's data for the TDH-49 earphone with data from this study. For this earphone type, there is again no significant statistical difference (at the 5% level) between the mean transfer SPL values. Nevertheless, from Figure 13 there is a systematic difference of about 3 dB at 6 kHz between the transfer SPL values for TDH-49 and TDH-49P earphones.

For three of the earphone types (see Table 2) both MX 41/AR and Model 51 cushions were used. It was found that for TDH-39 and TDH-39P earphones mounted on the IEC 303 acoustic reference coupler and for TDH-49P earphones mounted on the IEC 318 artificial ear, the cushion types could be taken as identical except at 5 kHz, 6 kHz and 6.3 kHz. Differences of around 2.8 dB at 6 kHz agreed with those observed by Dowson, McNeill and Torr[19] for the TDH-39 earphone. Differences of around 2.4 dB were observed a 6 kHz for the TDH-39P earphone, but for the TDH-49P, smaller differences of the order of 1.5 dB were found.

6 CONCLUSIONS

In physical terms, the acoustic reference coupler and the artificial ear present different acoustical loads to an earphone. The fact that the transfer SPL values for the TDH-39 and the TDH-39P earphones are significantly different at high frequencies shows that the output acoustical impedances of the two earphone types are also significantly different. This must in turn relate to differences in their physical form or construction.

The question arises as to how these two earphone types behave on the human ear. It is reasonable to suppose that there are significant differences between the acoustical loads represented by the acoustic reference coupler and the average human ear. Consequently, audiometric measurements made using a TDH-39P earphone, based on a calibration using the acoustic reference coupler and the RETSPLs for the type TDH-39, are likely to be in error at high frequencies. If we assume that the artificial ear is a reasonable match to the human ear this error is likely to be similar to the difference between the transfer SPL values for the TDH-39 and TDH-39P earphones, ie. between 5 and 10 dB at 6 kHz. Specifically, audiometric measurements made at 6 kHz using a TDH-39P earphone, calibrated using an acoustic reference coupler on the basis of RETSPLs for the TDH-39 earphone, would show hearing thresholds 5 dB to 10 dB higher than would measurements using a TDH-39 earphone.

This conclusion could be tested by carrying out subjective measurements of hearing threshold using the two earphone types on the same subjects and comparing the results. The otological normality of the subjects would not be critical, but for sufficient precision the subjects would need to demonstrate repeatable audiometric thresholds. Hearing loss at high frequencies is an early indicator of hearing disorder and hearing damage, and a study of this kind would establish whether audiometric measurements using the TDH-39P earphone are indeed in error at 6 kHz as a consequence of differences in performance from the type TDH-39.

In any event, an unsatisfactory aspect of present standards for air-conduction audiometry is the existence of two different standardised devices - the artificial ear and the acoustic reference coupler - and two associated sets of RETSPLs. The need for every calibration centre to hold two different calibration devices adds both cost and complication to the calibration of audiometers. Preferably, only one standardised device should exist for use with all types of supra-aural earphone. Furthermore, if this device was able to offer a good simulation of the human ear, only one set of RETSPLs would be needed. This is essentially the conclusion drawn by Delany[21] in 1967 but thirty years on the issue remains unresolved.

The IEC 318 artificial ear is recognised as being a better approximation to the human ear than the acoustic reference coupler, and is the device used for the calibration of all modern earphone types such as the Telephonics TDH-49P, Telephonics TDH-50P and Holmco 95-0 in conjunction with a single set of RETSPLs. It is concluded that a move away from the use of TDH-39 and TDH-39P earphones for air-conduction audiometry would be beneficial, both to avoid the problem of their differing performances and to facilitate the adoption of the artificial ear as the sole calibration device for supra-aural audiometric earphones.

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APPENDIX 1 COMPONENTS OF THE FOUR MEASUREMENT SYSTEMS

Acoustic reference coupler system no.1

artificial ear	Brüel and Kjær type 4152	serial no. 1387374
sound level meter	Brüel and Kjær type 2235	serial no. 1569379
filter set	Brüel and Kjær type 2625	serial no. 1564557
microphone	Brüel and Kjær type 4144	serial no. 1696335
adaptors	Brüel and Kjær type DB 0962, ZC 0020, AO 0027	

Acoustic reference coupler system no.2

artificial ear	Brüel and Kjær type 4152	serial no. 662666
sound level meter	Brüel and Kjær type 2235	serial no. 1382863
filter set	Brüel and Kjær type 2625	serial no. 1406919
microphone	Brüel and Kjær type 4144	serial no. 1233117
adaptors	Brüel and Kjær type DB 0962, ZC 0020, AO 0027	

Artificial ear system no.1

artificial ear	Brüel and Kjær type 4153	serial no. 1552229
sound level meter	Brüel and Kjær type 2235	serial no. 1382863
filter set	Brüel and Kjær type 2625	serial no. 1406919
microphone	Brüel and Kjær type 4134	serial no. 1611993
adaptors	Brüel and Kjær type ZC 0020, AO 0027	

Artificial ear system no.2

artificial ear	Brüel and Kjær type 4153	serial no. 190135
sound level meter	Brüel and Kjær type 2235	serial no. 1569379
filter set	Brüel and Kjær type 2625	serial no. 1564557
microphone	Brüel and Kjær type 4134	serial no. 1572359
adaptors	Brüel and Kjær type ZC 0020, AO 0027	

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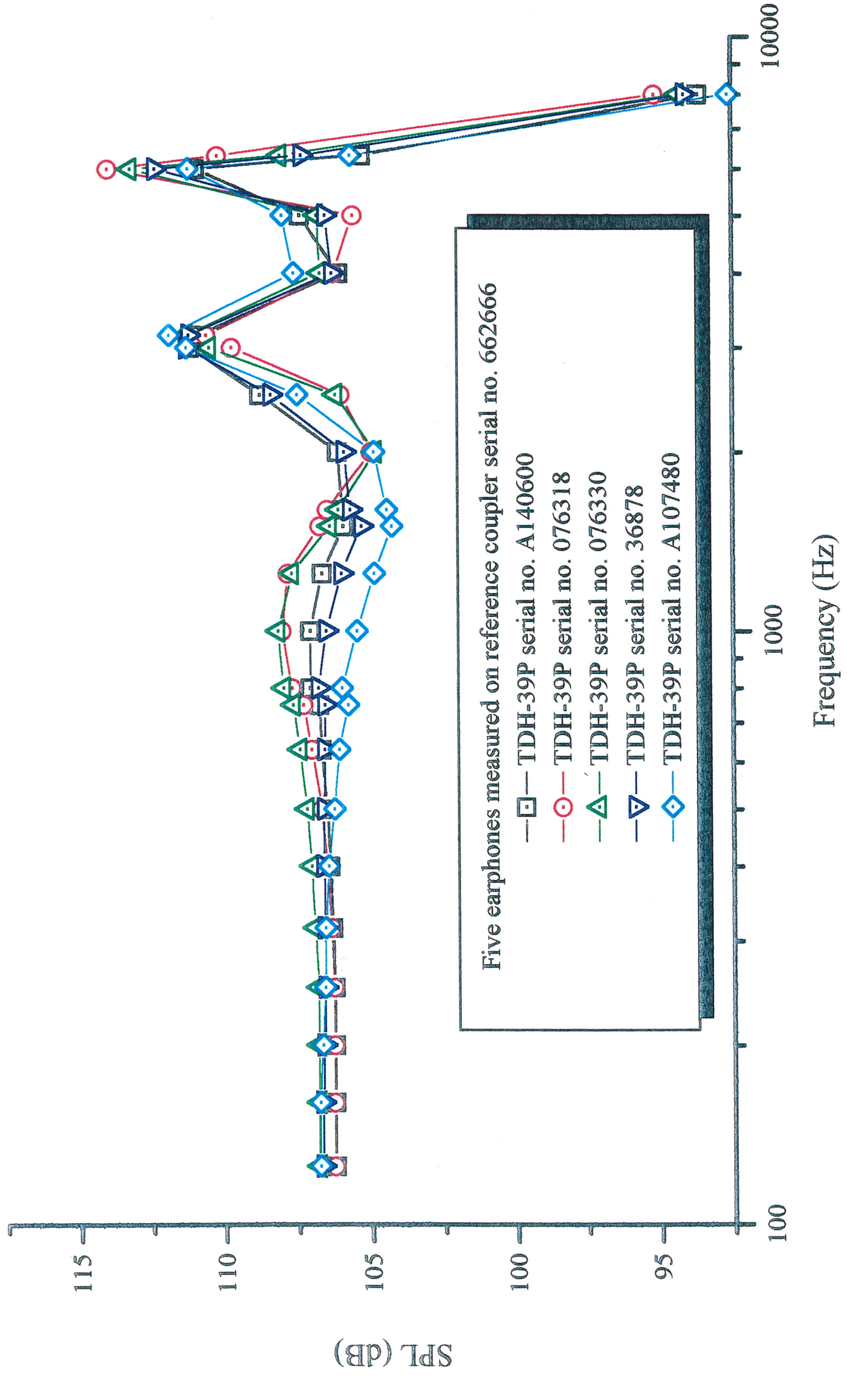

Figure 2 Mean frequency responses of five Telephonics TDH-39P earphones measured on an IEC 303 acoustic reference coupler

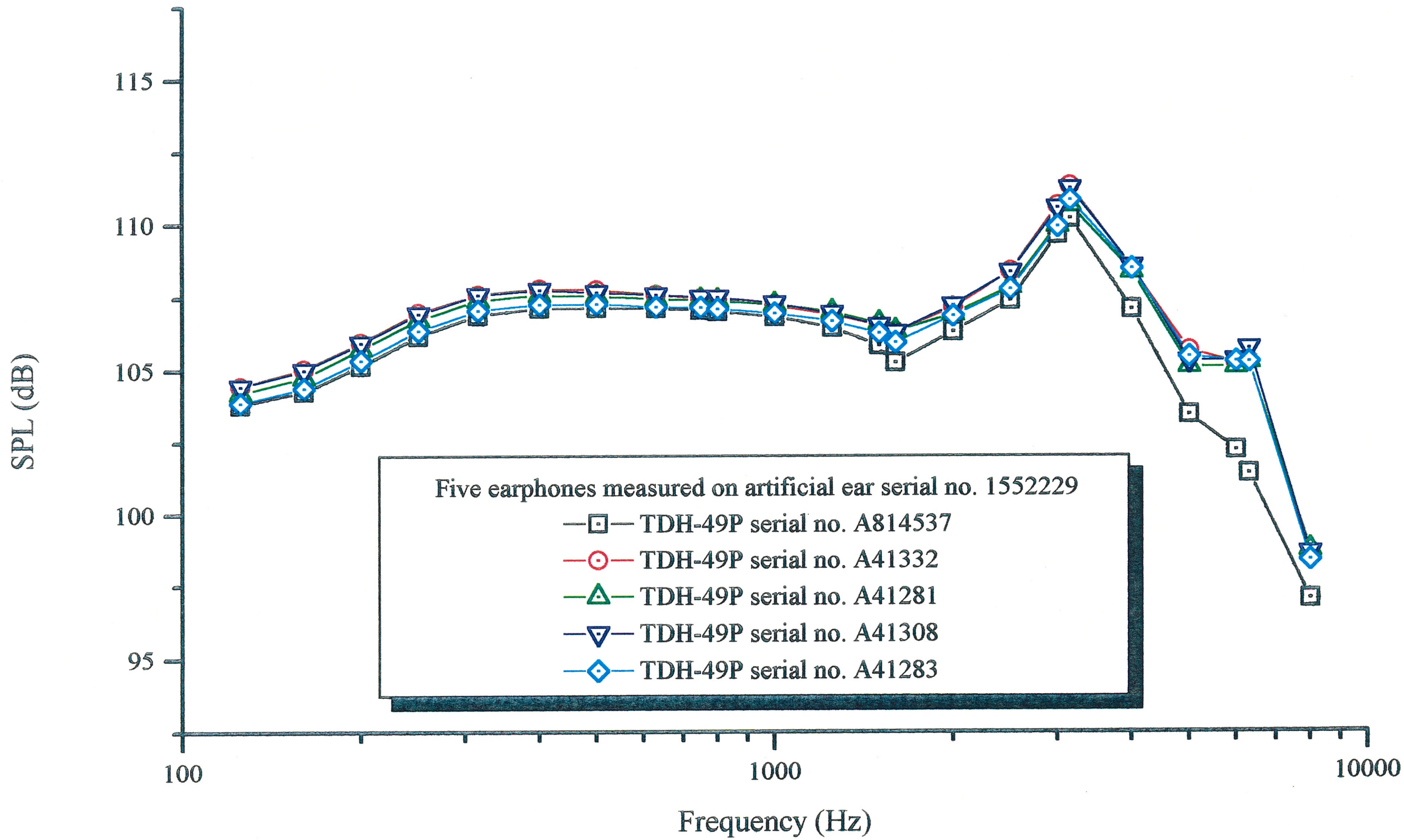

Figure 3 Mean frequency responses of five Telephonics TDH-49P earphones measured on an IEC 318 artificial ear

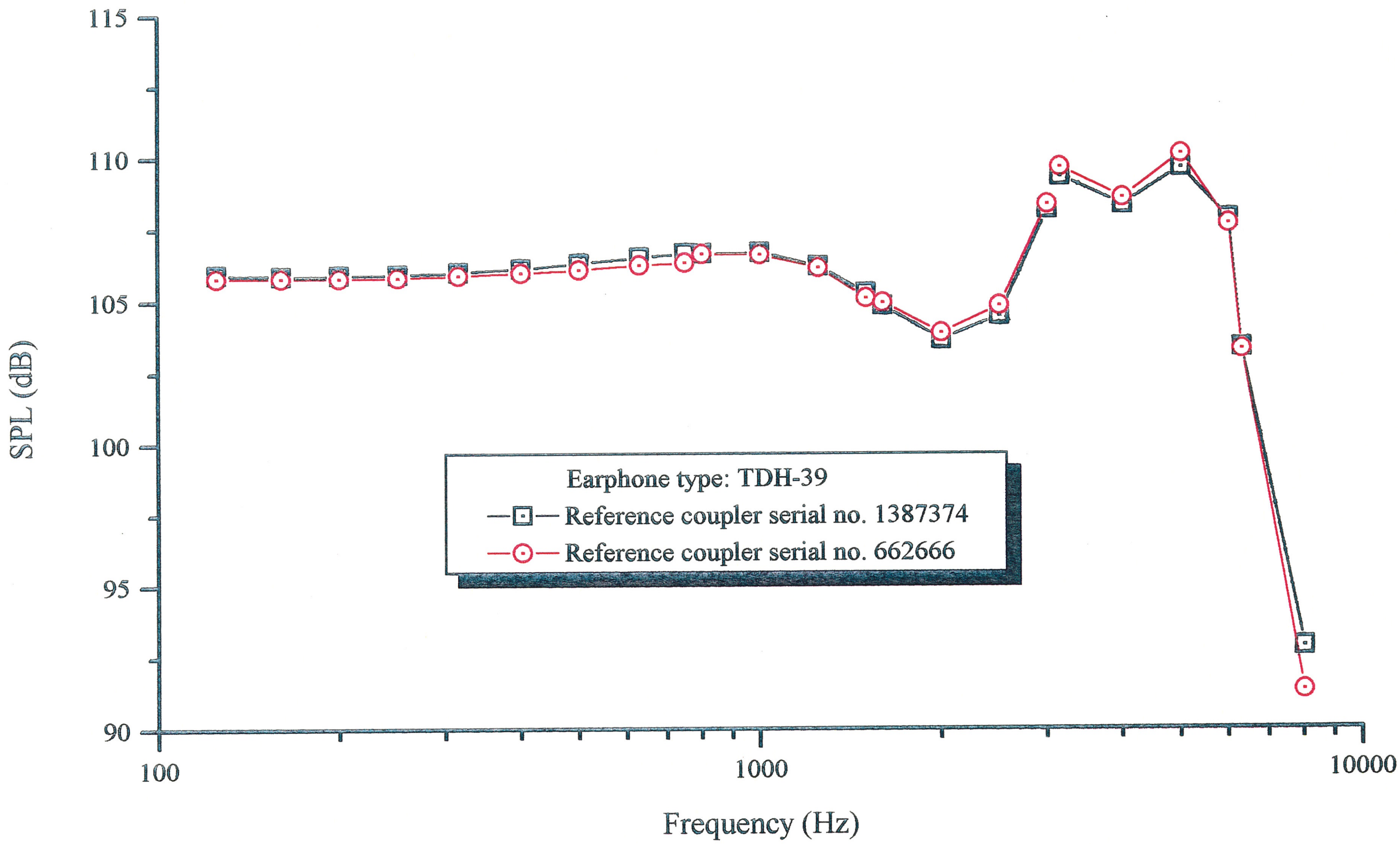

Figure 4 Overall mean frequency responses of five Telephonics TDH-39 earphones measured on two IEC 303 acoustic reference couplers

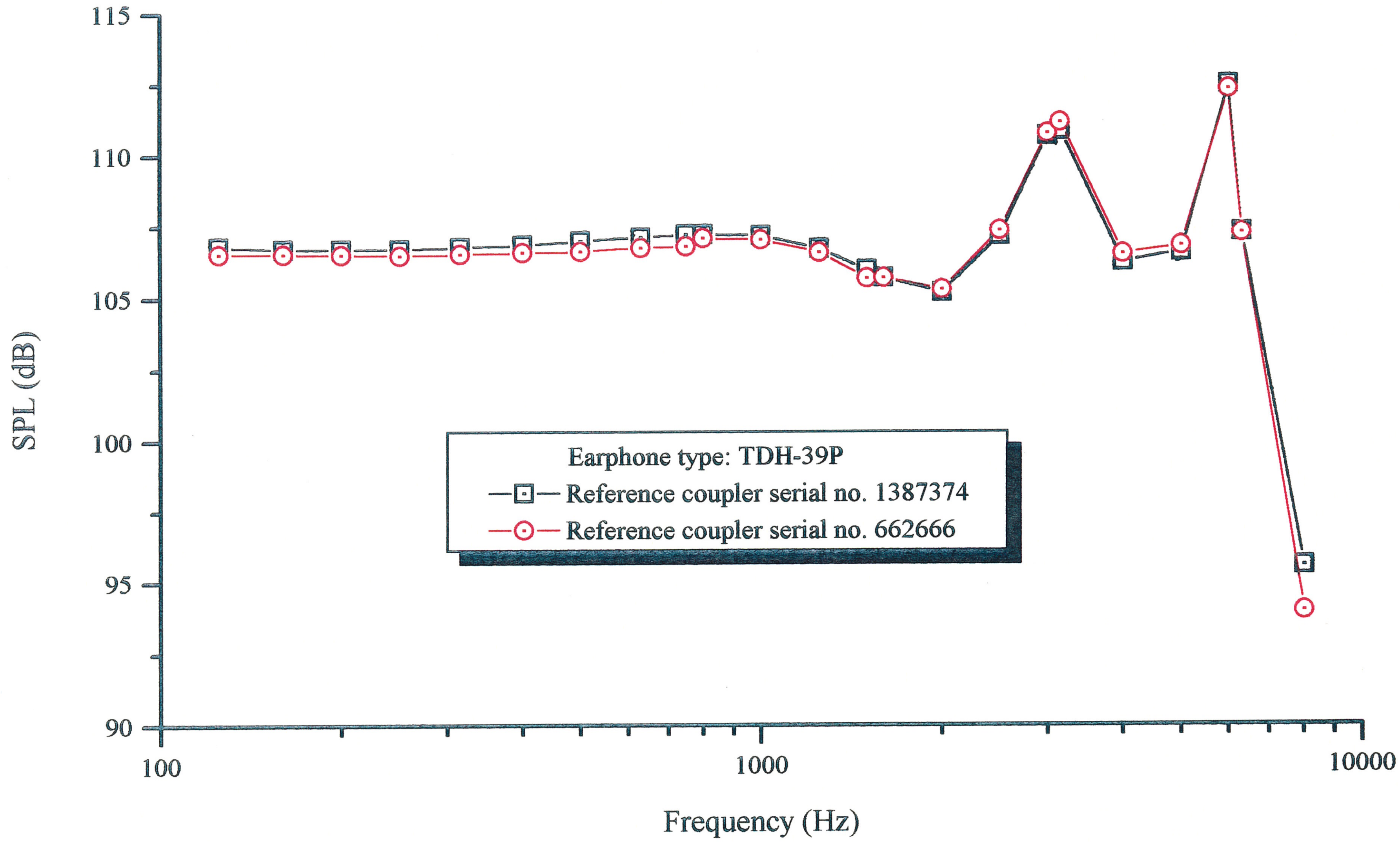

Figure 5 Overall mean frequency responses of five Telephonics TDH-39P earphones measured on two IEC 303 acoustic reference couplers

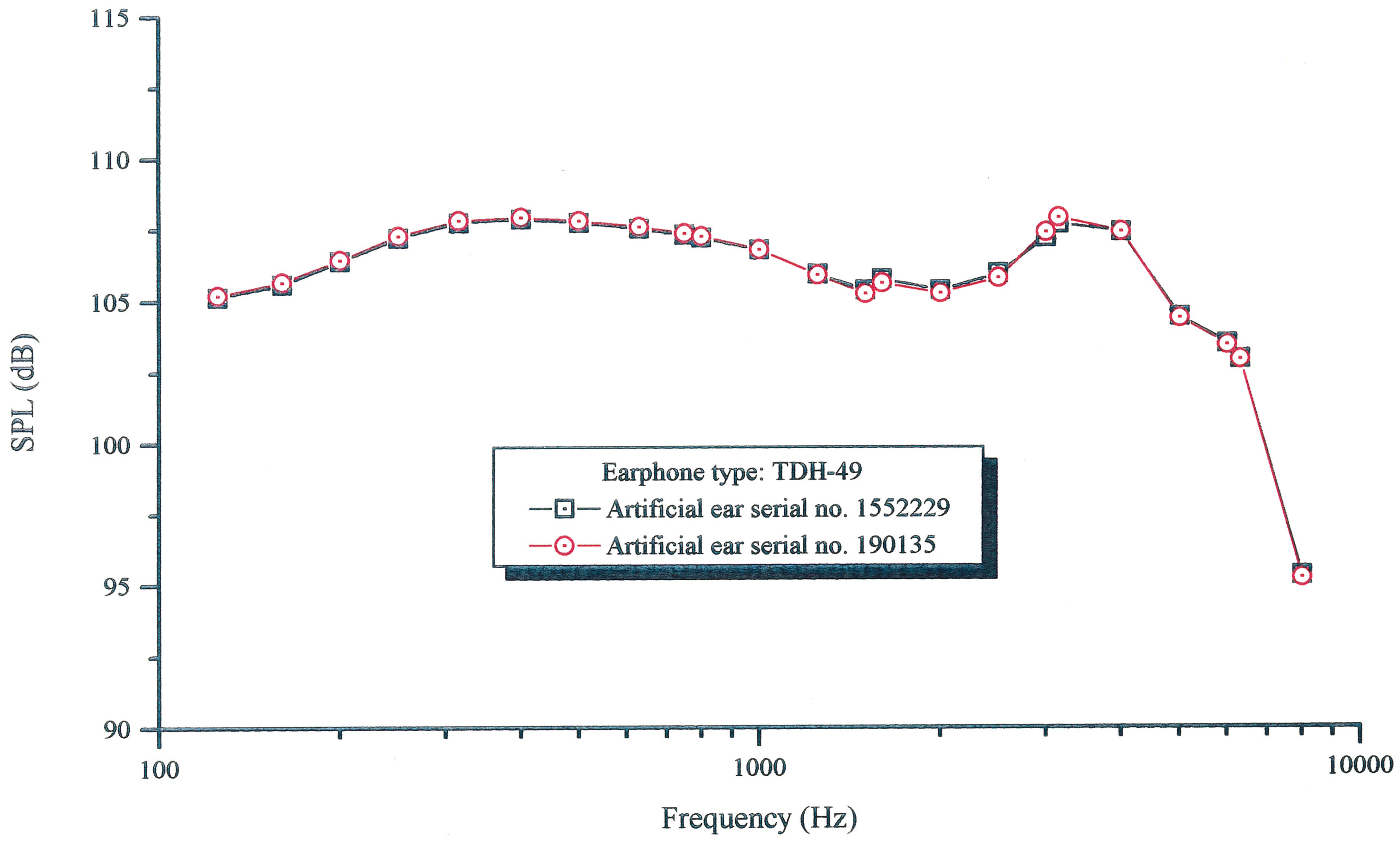

Figure 6 Overall mean frequency responses of five Telephonics TDH-49 earphones measured on two IEC 318 artificial ears

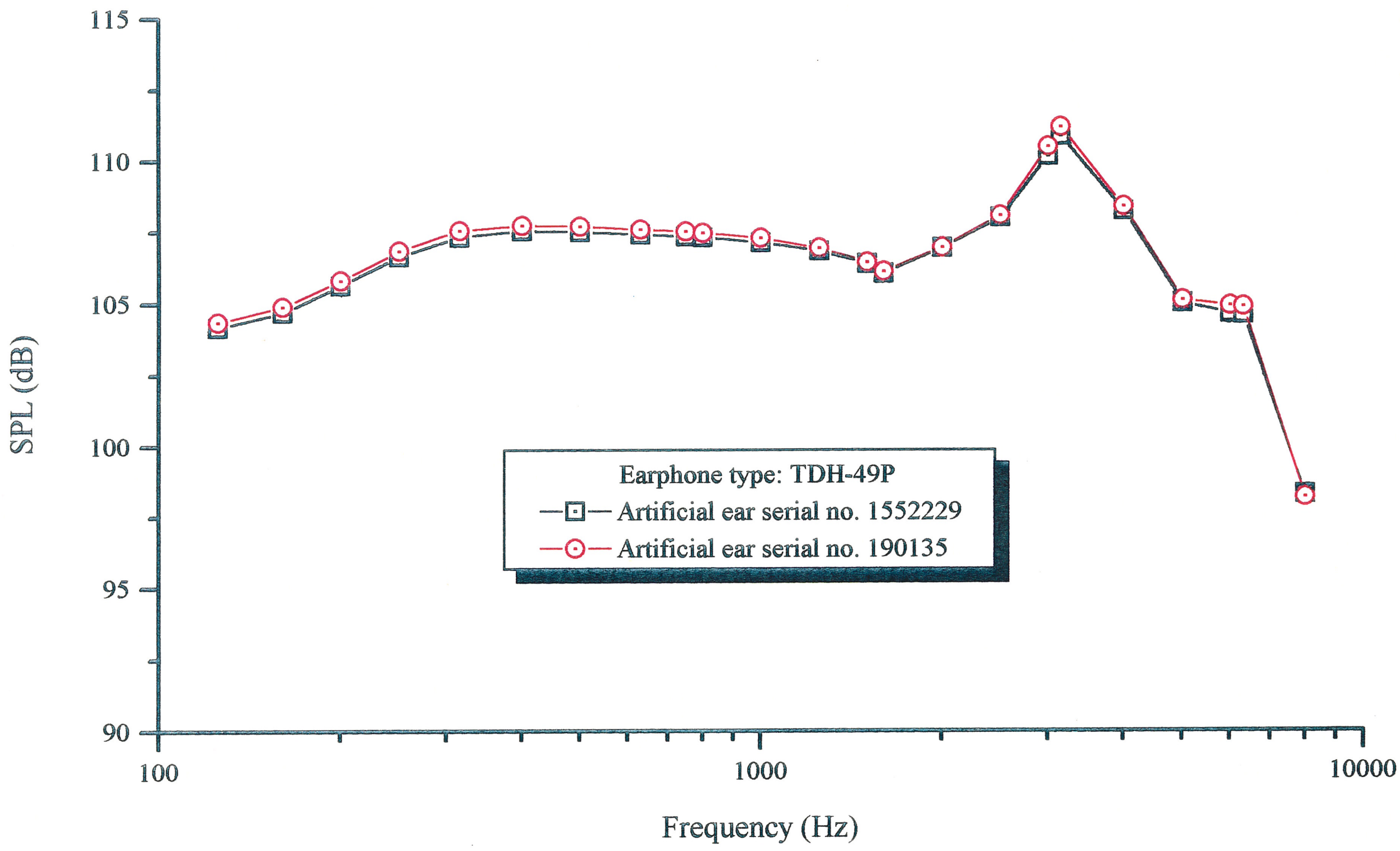

Figure 7 Overall mean frequency responses of five Telephonics TDH-49P earphones measured on two IEC 318 artificial ears

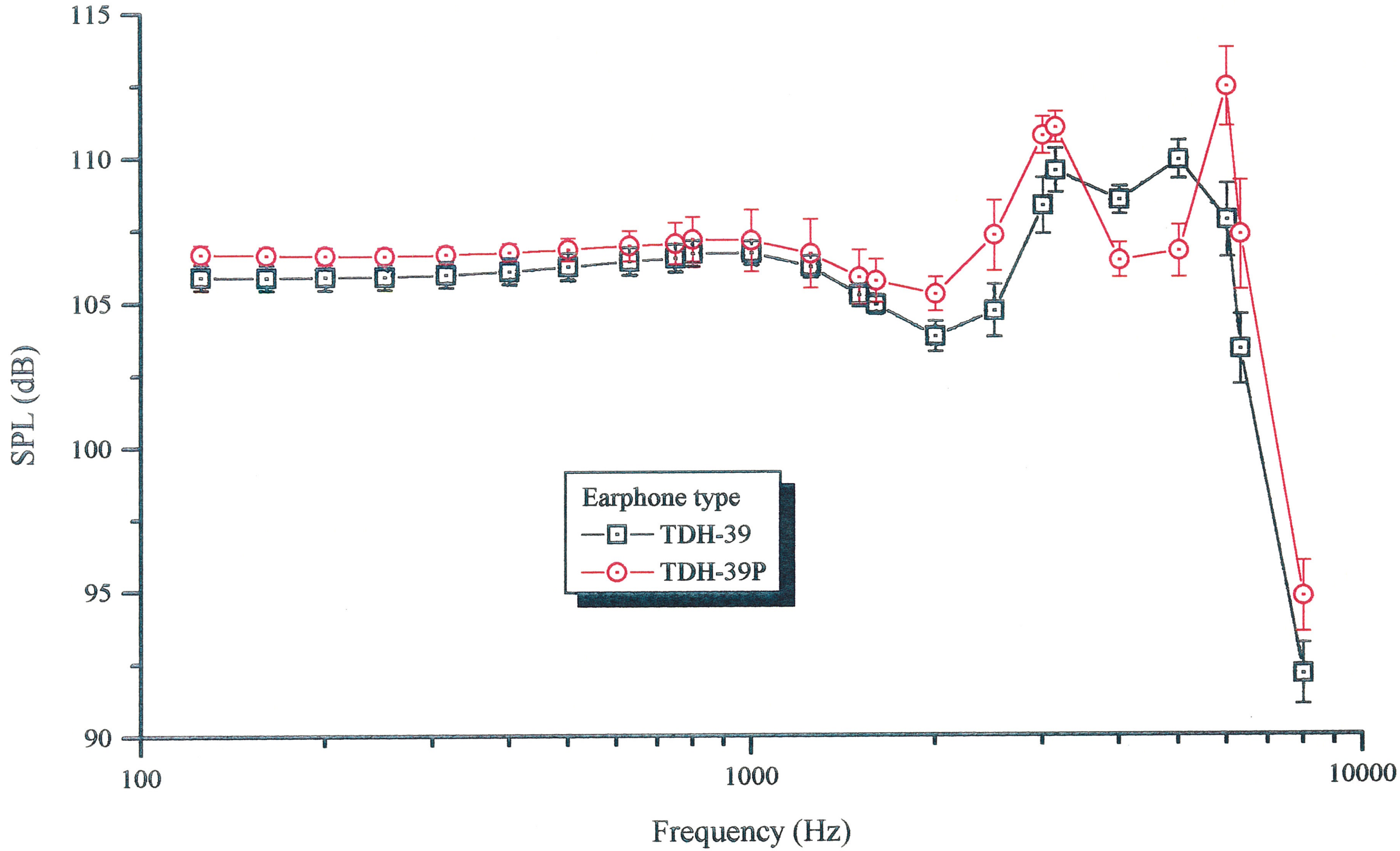

Figure 8 Grand mean frequency responses of the Telephonics TDH-39 and TDH-39P earphones measured using the IEC 303 acoustic reference coupler. The vertical bars show the standard deviation of the output sound pressure level of each earphone type (five earphones of each type measured on two reference couplers (n=10))

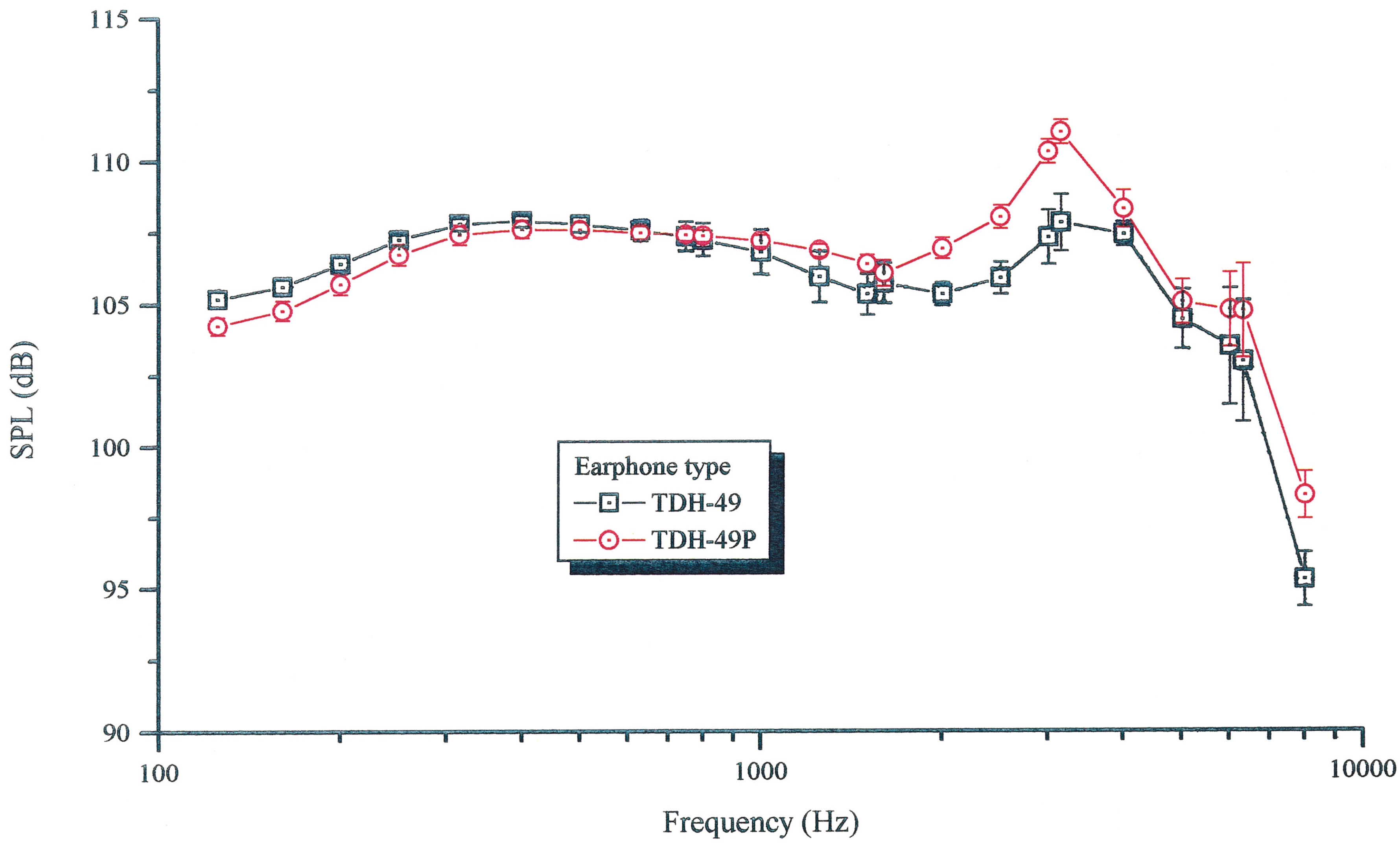

Figure 9 Grand mean frequency responses of the Telephonics TDH-49 and TDH-49P earphones measured using the IEC 318 artificial ear. The vertical bars show the standard deviation of the output sound pressure level of each earphone type (five earphones of each type measured on two artificial ears (n=10))

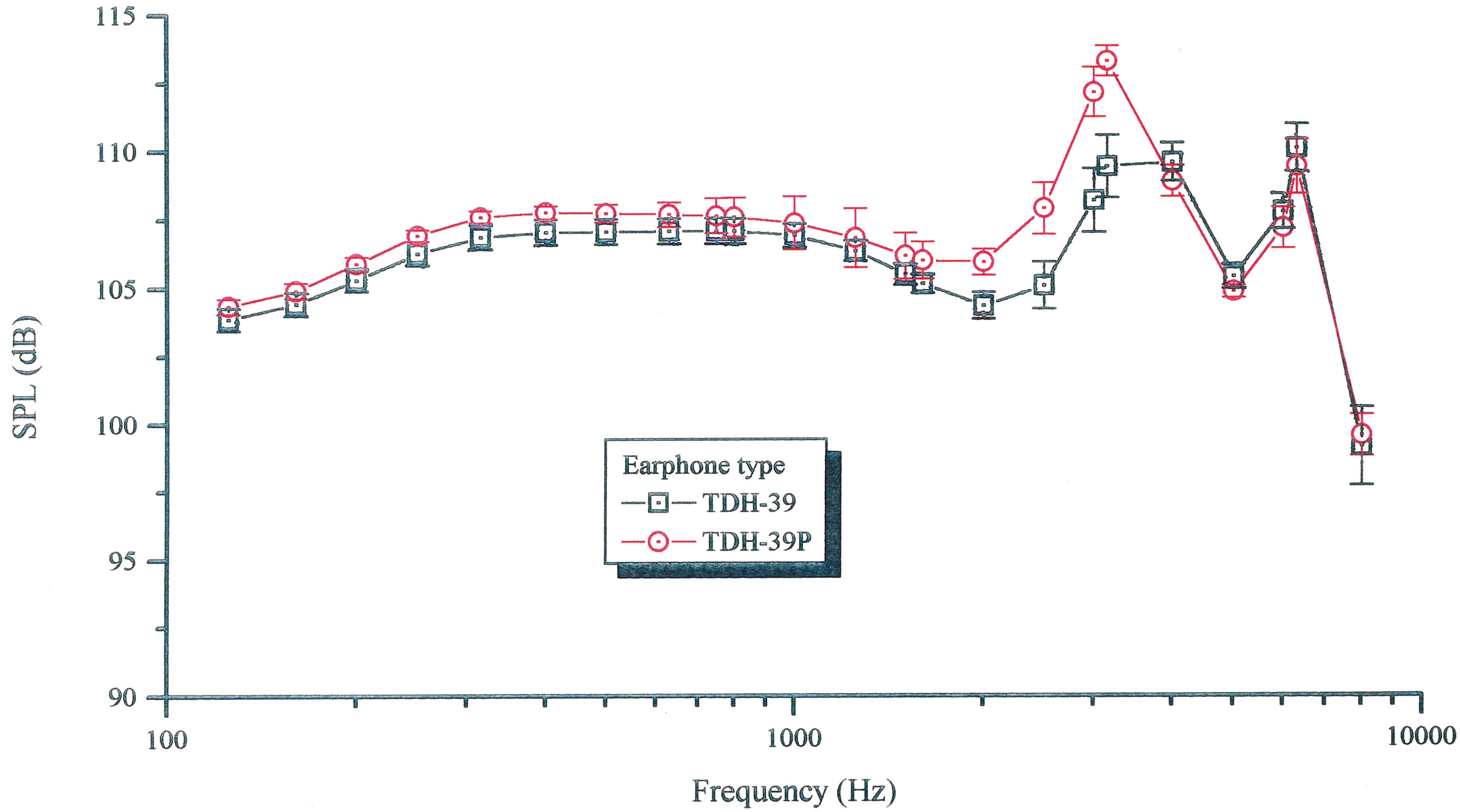

Figure 10 Grand mean frequency responses of the Telephonics TDH-39 and TDH-39P earphones measured using the IEC 318 artificial ear. The vertical bars show the standard deviation of the output sound pressure level of each earphone type (five earphones of each type measured on two artificial ears (n=10)). **Note** it is incorrect to use these earphone/ measurement system combinations for calibration purposes

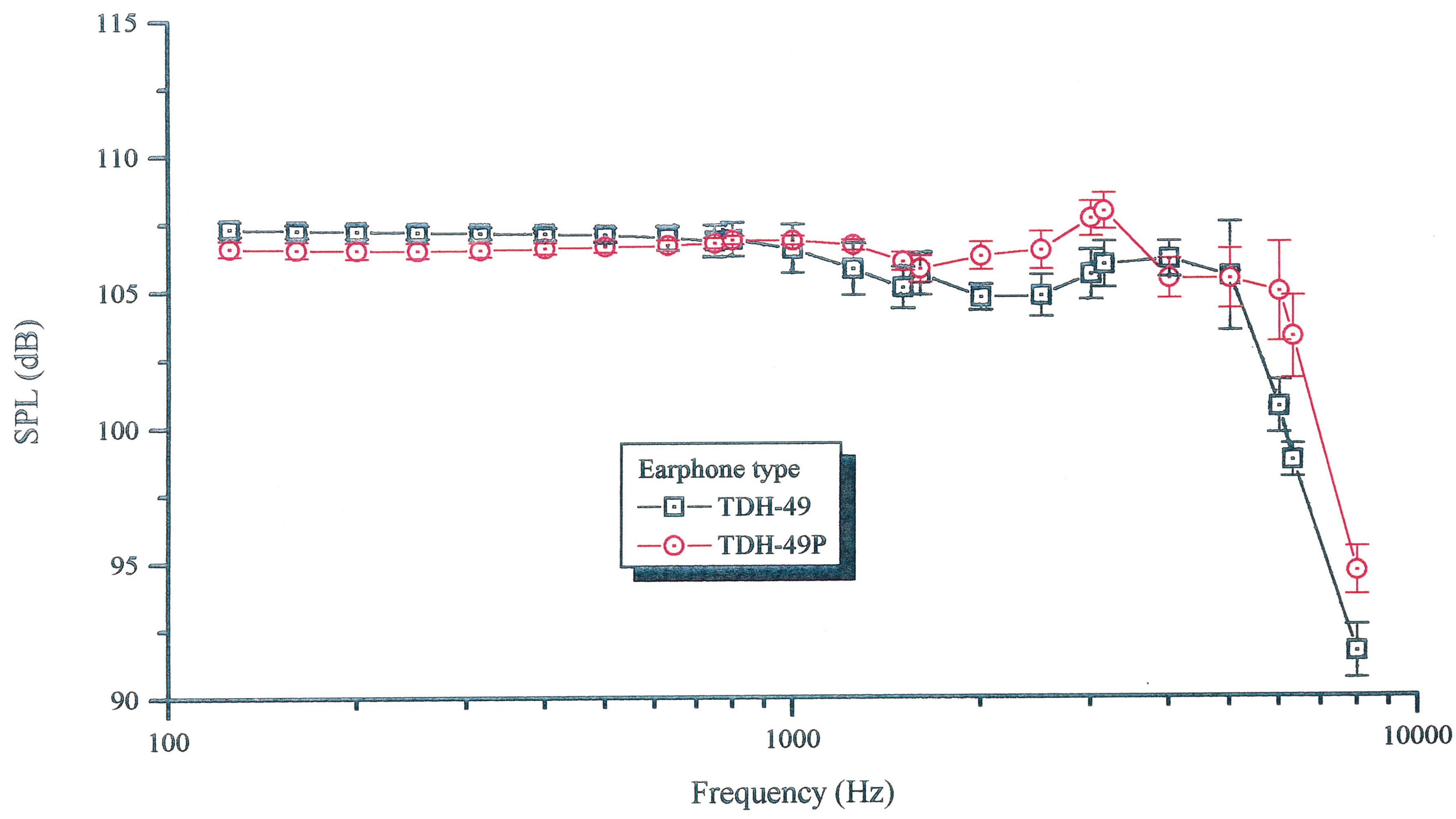

Figure 11 Grand mean frequency responses of the Telephonics TDH-49 and TDH-49P earphones measured using the IEC 303 acoustic reference coupler. The vertical bars show the standard deviation of the output sound pressure level of each earphone type (five earphones of each type measured on two reference couplers (n=10)). **Note** it is incorrect to use these earphone/ measurement system combinations for calibration purposes.

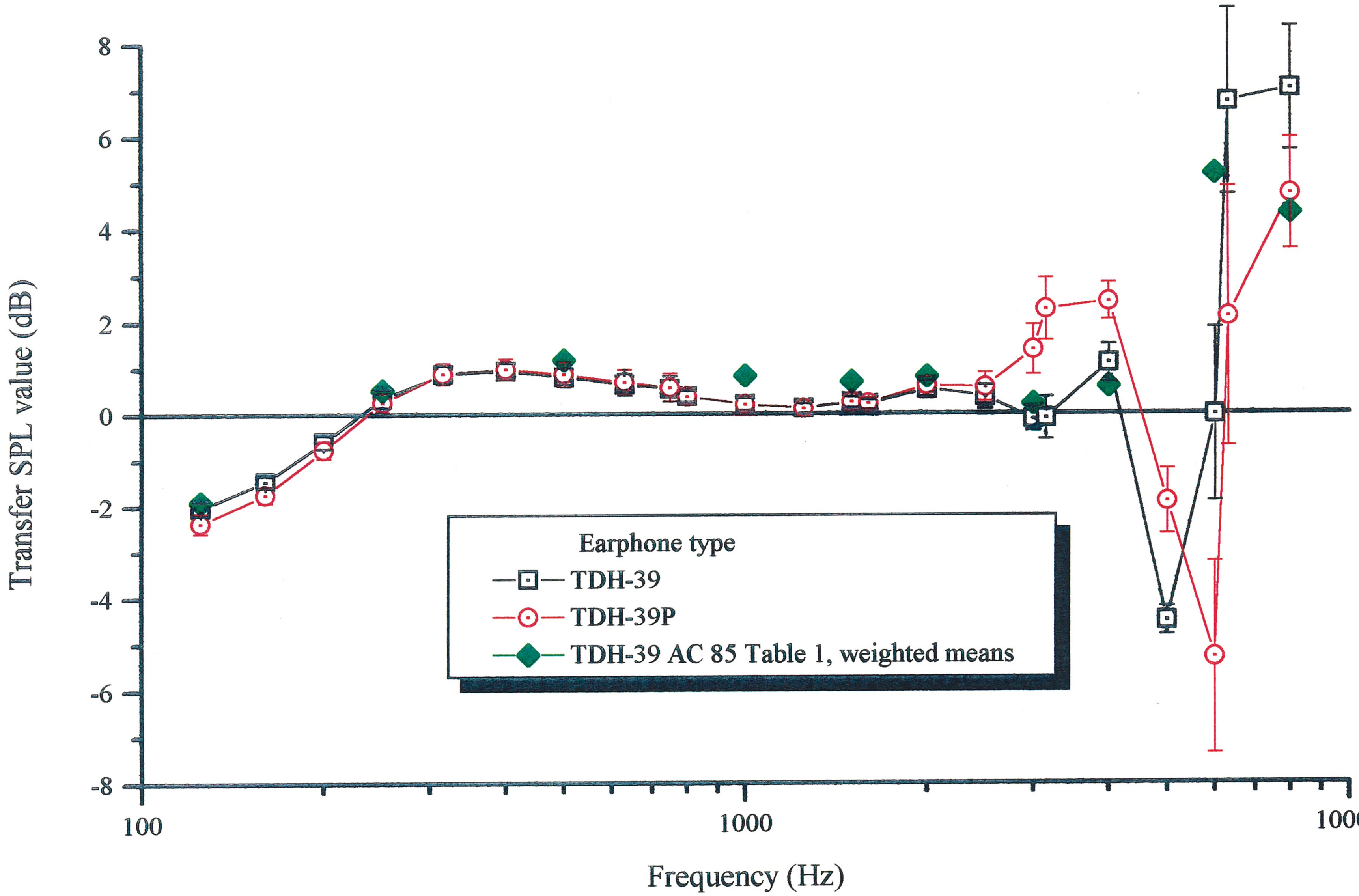

Figure 12 Mean transfer SPL values of Telephonics TDH-39 and TDH-39P earphones. The vertical bars show the standard deviation of the transfer SPL. The figure also shows Robinson's[10] data.

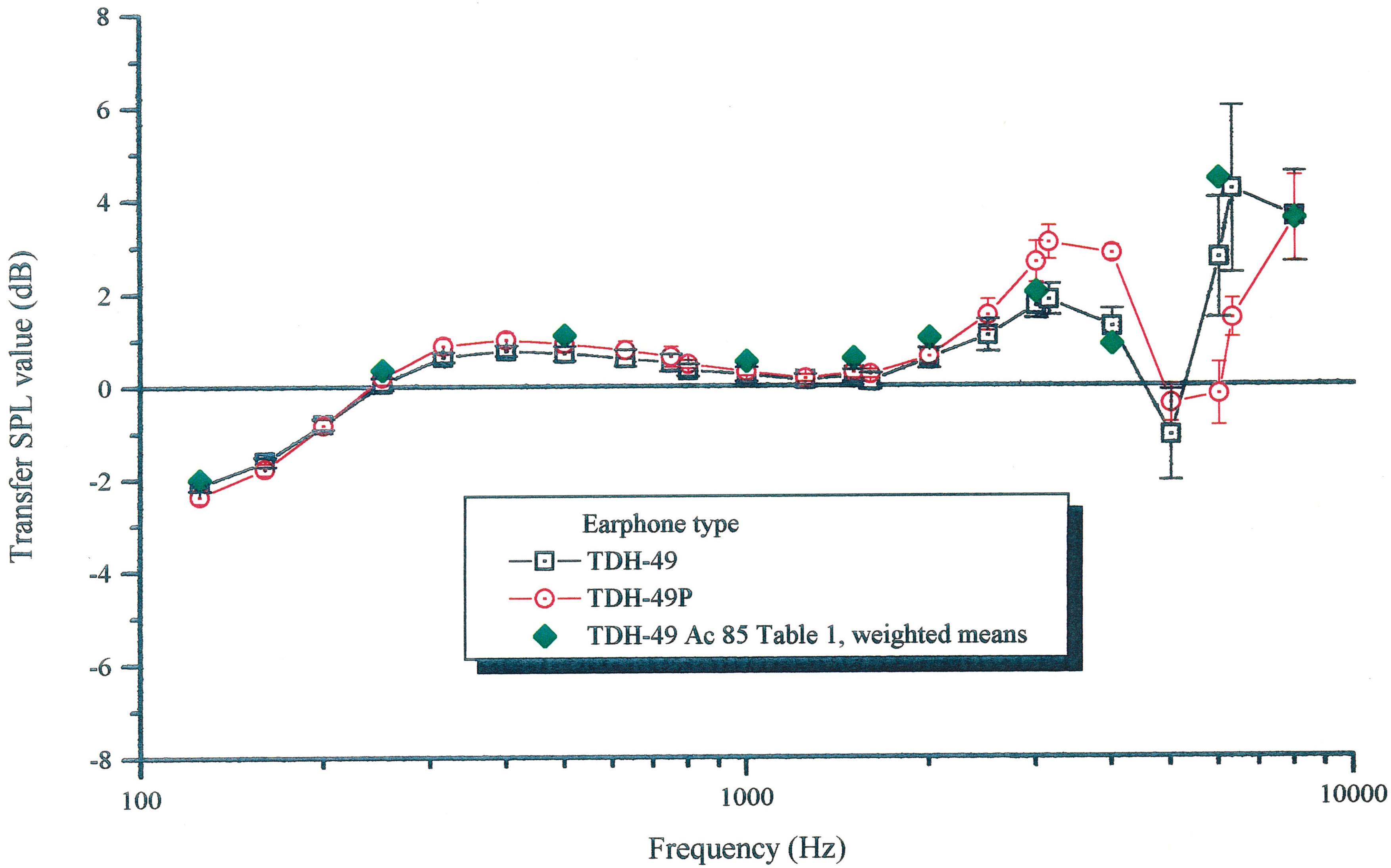

Figure 13 Mean transfer SPL values of Telephonics TDH-49 and TDH-49P earphones. The vertical bars show the standard deviation of the transfer SPL. The figure also shows Robinson's[10] data.