EFFECT OF DAMPERS ON ELECTROACOUSTIC CHARACTERISTICS OF BEHIND-THE-EAR HEARING AIDS

REGISTER NO. M.9101

AN INDEPENDENT PROJECT SUBMITTED AS PART FULFILMENT FOR THE
FIRST YEAR M.SC.[SPEECH AND HEARING] TO THE UNIVERSITY OF MYSORE

ALL INDIA INSTITUTE OF SPEECH AND HEARING, MYSORE - 570 006
MAY 1992

Dedicated

to

Ajji, Amma Appa

CERTIFICATE

This is to certify that this Independent Project entitled "EFFECT OF DAMPERS ON ELECTROACOUSTIC CHARACTERISTICS OF BEHIND-THE-EAR HEARING AIDS" has been prepared under my supervision and guidance.

Nikam

MYSORE **Dr.(Miss)S.Nikam**
MAY 1992 . GUIDE

CERTIFICATE

This is to certify that the Project entitled ***"EFFECT OF* DAMPERS *ON ELECTROACOUSTIC* CHARACTERISTICS *OF BEHIND-THE-EAR* HEARING AIDS"** *is a bonafide work, done in part fulfilment for the First year Degree of Master of* Science (Speech *and Hearing) , of the student with Register No.* M. *9101.*

DIRECTOR

MYSORE ALL INDIA *INSTITUTE OF SPEECH & HEARING*
MAy 1992 MYSORE - 570 006

DECLARATION

I here by declare that this Independent Project entitled **"EFFECT OF DAMPERS *ON* ELECTROACOUSTIC CHARACTERISTICS OF *BEHIND-THE-EAR* *HEARING AIDS*"** *is the result* of *my own study under the guidance of Dr. (MISS)S.Nikam, Professor and Head of the Department of Audiology, All India Institute* of *Speech and Hearing, Mysore, has not been submitted earlier to any University for any other diploma or Degree.*

MYSORE
MAY *1992*

REGISTER *NO.M.9101*

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EFFECT OF DAMPERS ON ELECTROACOUSTIC CHARACTERISTICS OF BEHIND-THE-EAR HEARING AIDS

INTRODUCTION

Acoustics is defined as the science of sound. This science of sound captures our attention, when communication is involved. Sound transmission has an important role to play in communication. This is extremely so in the rehabilitation of the hearing impaired.

When we think of the rehabilitation for the hearing impaired, the first thing that strikes our mind is the hearing aid. Hearing aid is an electroacoustic device which aids in amplification of sounds. There are various types of hearing aids which can be worn, and body level- hearing aid, behind-the-ear hearing aid, In-the-ear hearing aid are some gross categories. Having a hearing aid is not sufficient enough. One needs to have a coupling device which enables the receiver of the hearing aid to sit in the ear. This coupling device is termed earmold. Earmold, though it seems insignificant when compared to a hearing aid, research have shown that quality of sound output from hearing aid can further be modified at the level of ear mold. These techniques involving the principle of acoustics have been known to the scientists for over a century and to the industry for decades but have only recently been put to use.

For the researcher and dispenser, as reported by Gerling [1981]* the new earmold technology has some basic philosophic considerations. They are:

1. To preserve the normal eardrum - freefield transformation.
2. To preserve the balance acoustically between the high and low frequencies in normal speech spectrum.
3. To extend the high frequencies in wearable hearing aids.
4. To minimize and / or eliminate the standard peak in the hearing aid responses at 1000 - 1500 Hz for many mild and moderate losses.
5. To gradually slant upwards the frequency response of a hearing aid.
6. To keep the output of a hearing aid within the client's dynamic range.

These are accomplished by adjusting the frequency response of the hearing aid with special attention to the ear mold and assisted plumbing. Individual adjustments to low, mid and high frequencies with the use of venting, damping and horn effects respectively can be made.

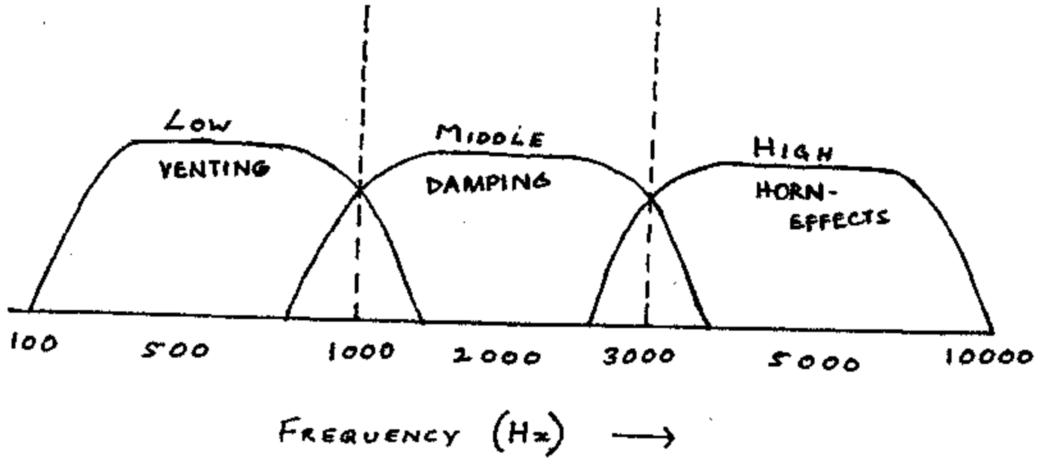


Fig.l. Earmold modification and frequency of interest.

Among the modificatidns, of interest with respect to the present is the acostic modifications of the ear mold or the coupling device of the hearing aid to the ear. This interest is further restricted to the use of dampers in the coupling device and used with respect to the behind-the-ear hearing aids.

The aim of the present study is to use imported dampers of different specified values and study their effect and effectiveness on the electroacoustic characteristics of behind-the-ear hearing aids.

REVIEW OF LITERATURE

As seen in the previous section, individual adjustments to low, mid and high frequencies can be made with the use of venting, damping and horn effects respectively.

VENTING: Earmold venting appears to have been used first by Grossman [1943]* in combination with button receiver system as reported by Lybarger [1985]. Vent is defined as the opening from the surface of an earmold to its sound input channel. It is an intentionally produced leak. [Langford, 1975 cited in Pollack 1975].

PURPOSES:
a. Barometric equalization.
b. Eliminates blocked up feeling in the ear.
c. Ventilates ear canal, alleviates discomfort, heat and humidity.
d. Reduces occlusion by earmold.
e. Improves sensitivity.
f. Radical modification of frequency response - low frequency reduction.

ACOUSTIC DAMPING: Tubing resonance and Helmholtz resonance [produced by the acoustic complience of the air cavity in front of the hearing aid receiver] causes sharp peak around 1000 Hz in the output of the behind-the-ear hearing aids as measured in 2cc couplers and 2000 Hz or higher for In-The-Ear hearing aids [Skinner,1988]*. These can be excited by sharp transient sounds, causing a ringing or echoing sound. Various acoustic resistance or damping elements have been used to smoothen the frequency response of the hearing aid - earmold system and to control gain and saturation output.

The effect of acoustic dampers on the hearing aid response are determined by:

1. The value of the acoustic resistance, higher value causing more flattening of peaks.

2. The number of dampers used.

3. Location of damper[s] in the acoustic transmission system.[Lybarger, 1985] Killion[1977]* and Cox[1979] reported that an acoustic damping element can only dissipate energy when there is air flowing through the element. As the air flowing through the element increases, the effectiveness of the damping increases.

Cox[1979] has pointed out that for wavelength resonances the antinode of the standing waves in a tube represents positions of maximum air flow, the location of which for a given frequency and length of tubing can be mathematically calculated. With this, one can bring about a selective reduction in resonance peaks at certain frequency by placing the damping element at the antinode location of unwanted resonance frequencies.

Killion[1977]* reported that for damping to occur the acoustic damping element should have a characteristic or surge impedence equal to that of the earmold tubing. A damping element that has a resistive value equal to the surge impedence will properly terminate the transmission line [that is, hearing aid or earmold tubing] resulting in absorption of all incidental energy thereby avoiding the reflections of energy which are basically responsible for the resonant peak. The energy reflected at the point of impedence discontinuity creates standing waves and the consequent wave length resonances. If the energy is completly obsorbed at the end of the tubing line, no reflection and no standing wave occurs. Additionally, when the tubing of amplification systems are properly terminated, the transmission of sound down the tube is nearly independent of the length of the tubing between the hearing aid receiver and the damping element.

Chasin[1983] stated that the exact positioning of resistor in the tubing is not clinically significant as long as it is within 5mm of the target position.

The resonance frequency of a tube open at one end is

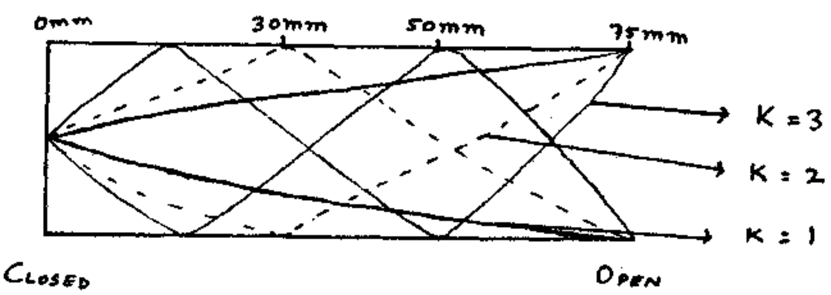
$$f= [2k - 1]\ v/41$$

where v= velocity of sound,

1= effective length of earhook- tubing path and k is mode of resistance.

eg; If l=75mm, the first 3 modes of resistance are :

$f_{k=1} = 1100$ Hz; $f_{k=2} = 3300$ Hz; $f_{k=3} = 5500$ Hz.



. Fig.2.

Volume velocity is greatest at a point where there is an antinode [or loop] in standing wave pattern. Greater the volume velocity, more effect will the acoustic resistance have [ie] resistance will have little effect if placed at noded position.

Chasin[1983] also state that Acostic resistance primarily affects or damps the llOOHz peak, both in frequency response and SSPL 90 curve. This allows the user to turn up volume control and make more use of other gain that hearing aid has to offer, especially in high frequency region. Also, damping SSPL 90 allows the aid to be set at a higher MPO level. It allows the user to have slightly more gain without danger of tolerance problem. This eliminates peak clipper or AGC circuit which creates distotion and more adverse S/N ratio. Thus it can be used as an efficient output limiting system.

DAMPING ELEMENTS:

The resistive or damping elements include the following:

a] Lamb's wool,

b] Sintered filter,[sintered metal pellets],

c] Cotton,

d] Fused plastic mesh etc.

Lamb's wool:

Inserting lamb's wool in the tubing or mold of the coupler system can be one method of damping [Langford 1975]. Greater the density of packing, greater is the damping effect.

Sintered filter:

As reported by Decker [1974],* Langford* [1985], an alternative method of controlling the spectrum by mechanical means is to use sintered filters in the tubing. These are small cylinders of stainless steel balls sintered together [welded] in such a manner that predicts the degree of acoustic attenuation that can result. They are used to reduce lower portions of speech spectrum [Fl & F2] with minimal effects on high [F3]. These are considered to have a repeatability of +/-1 dB for same basic frequency response.

George and Barr - Hamiston [1978] also reported that for earmolds provided with high gain hearing aids, the blocked sensation can be removed without altering the output and occurance of acoustic feedback using sintered venting.

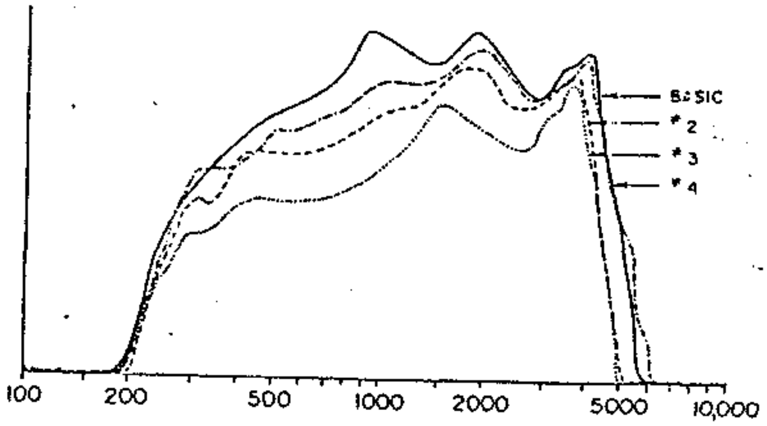


Fig.3.Effects of sintered filters on heraing aid response.

Other dampers: Acoustic dampers have been successfully made from discs with a small holes(s), fine metal screens and porous stainless steel plugs. The type that has found greater use in recent years (Knowle's BF series) is made from very fine fused plastic mesh mounted in a small metal ferrule (ring) which fits into No.13 tubing. Dampers of this type having resistance values of 680, 1000, 1500, 2200, 3300 and 4700 (Cgs) acoustic ohms are currently available (Lybarger, 1985).

To obtain optimal response smoothening in a particular frequency region, the dispenser identifies the frequency of the unwanted resonant peak, calculates the surge impedence of the tubing (1400 when No.13 tubing is used), and places the appropriate damping element at the desired antinode location in the tubing. Killion(1977)* reports that this process may be simplified by placing two appropriate damping elements 20 & 35mm back from the tip of the earmould.

Skinner(1988) reported that some manufacturers use a single 680, 1500, 2200 acoustic ohms dampers in the earhook rather than near the earcanal because the moisture from earcanal can clog the damper and cut off the sound. When the damper is placed at the tip of the earhook, there is little effect on the resonant peak at 2000 Hz because of the dampers location at 1/4 wavelength node (Lybarger, 1985).

Other properties: In addition to smoothening the resonance peaks, in the output of the amplification system, which often reduces patient's complaint assisted with tolerance problems, this can reduce feed back problems which may be assisted with sharp peaks in the output of the system (Killion, 1980).

In a recent study, Cox and Gilmore(1986) found that eight out of ten hearing impaired listeners found hearing aids without dampers to produce slightly clearer, more pleasant sounding speech than those with dampers. Though further research is implicated, this suggested that acoustic dampers did not necessarily improve sound quality.

METHODOLOGY

Selection of Hearing aids:

A total of ten hearing aids were taken for the study. All these hearing aids were Behind-the-Ear type of hearing aids. These hearing aids belonged to the used group as they were collected from hard-of-hearing children attending speech therapy at a Speech and Hearing Centre. The hearing aids selected were both from Indian and foreign manufacturers.

Selection of dampers;

A total of nine sintered filters were selected as dampers. These were imported from Hal-Hen Company, Inc., U.S.A. who are one of the leading manufacturers of earmould materials and acoustic modifiers of earmoulds. These dampers had specific acoustic ohm values or attenuation in dB values, which are shown in the Table-1.

Type of sintered filter	Acoustic Resistance in ohms	Attenuation in dB at 1K
White (Wl)	680	—
Green (Gl)	1500	-
Yellow (Yl)	4700	-
Orange (01)	-	3 dB
Green (G2)	-	6 dB
Brown (BR1)	-	9 dB
Yellow (Y2)	-	12 dB
Grey (GRl)	-	15 dB
Red (Rl)		18 dB

TABLE 1: Showing acoustic ohm/attenuation in dB values of dampers

Test Environment:

Tests were carried out in an air-conditioned sound treated room. The ambient noise levels inside the room were with in permissible limits.

Instrumentation:

1. Hearing aid test system (Fonix 6500)
2. 1/2" test microphone
3. 2cc couplers HAl and HA2.

The instruments were connected as shown in Appendix-A. Inside the hearing aid test box (Fonix 6500) the different connections made were, as follows.

(a) The test mic was kept at the left side of the reference point (ring).

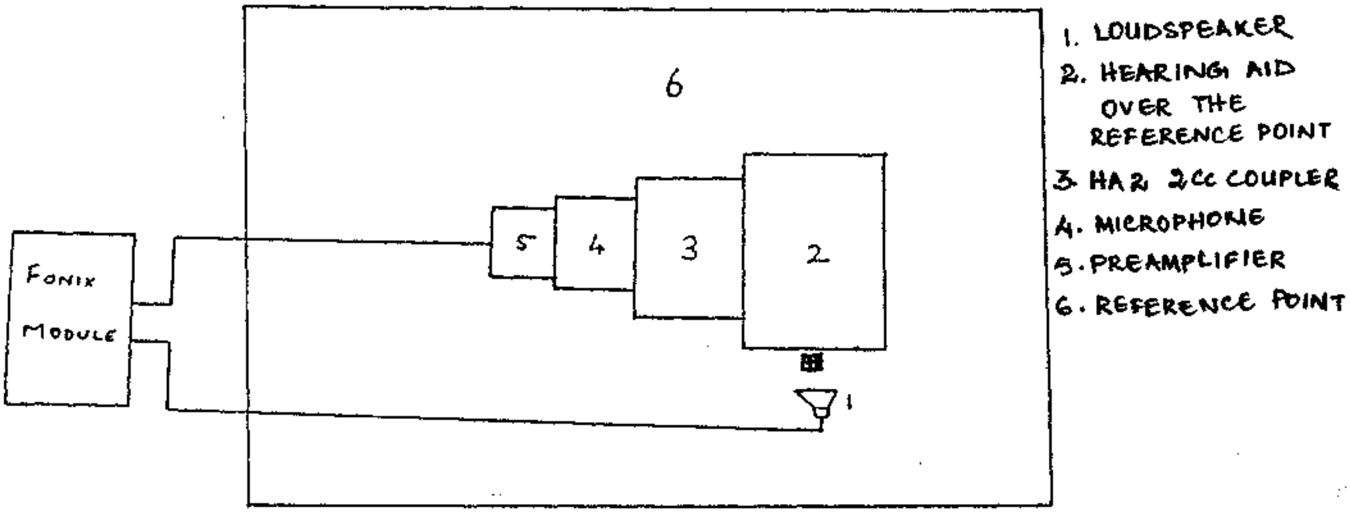
(b) The test mic was connected to the 2cc coupler (HA2) which was connected to the hearing aid by means of an adaptor. The hearing aid was given a constant power supply of 1.5 volts from the inbuilt power supply through battery substitution pills.

(c) The test mic was connected to the 2cc coupler (HAl) to which the earmould was coupled. To the tip of the tubing of the earmould the ear hook of the Behind-the-Ear hearing aid was attached. Again the power supply was from the test box.

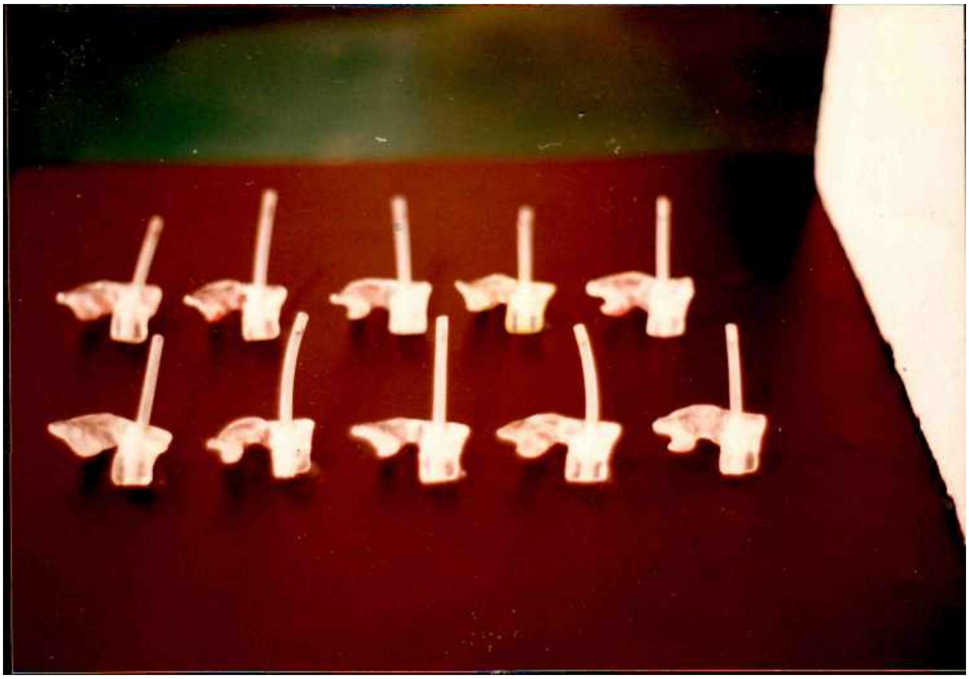
(d) The test mic was connected to the 2cc coupler (HA1) to which the earmold was attached. Different dampers were inserted into the tubing of the earmold and the earhook of the hearing aid was connected to the tubing in such a way that the damper was in contact with the tip of the ear hook.

Some constants maintained:

1. The length of the tubing.
2. The depth of insertion of the ear hook into the tubing of the earmold.
3. The placement of the mic of the hearing aid within the hearing aid test box.
4. All dimensions of the earmold including the length of the sound bore and diameter of the sound bore.
5. The voltage to the hearing aid by the use of inbuilt power supply in the hearing aid test box.
6. The voltage to the instrument by the use of voltage stabilizer.



Block diagram of hearing aid test system.



Photograph 1.   Showing ear molds with sintered filters

Photograph *1.*   Showing connections within the hearing aid test system.

Photograph 3. Setup of instruments

Photograph 4- Display of Elector Acoustic Characteristics.

PROCEDURE:

Calibration and Leveling:

Calibration was done before the instrument was used for the present study.

The sound chamber lid was opened and the instrument was kept on for around 30 minutes for allowing the instrument to warm up.

Leveling was done every time the instrument was switched on by placing the mic on the reference point and pushing the "level" button, the sound chamber was calibrated for consistent test results.

The electroacoustic characteristics of the hearing aid was measured under 3 conditions,

Condition-I:

The electroacoustic characteristics measurements were obtained using the hearing aid directly coupled to the microphone with the help of an adaptor and 2cc coupler (HA2).

The hearing aid was kept at "M" position. The power supply was given to the hearing aid from the inbuilt power supply through battery substitution pills. The volume control on the hearing aid was turned to "Full-On" position and the hearing aid microphone was kept at reference position. The lid of the hearing aid test box was closed. IS mode was selected by pushing "IS" button. The screen displayed the maximum SSPL 90, HFA SSPL

90, and HFA-FOG values. Then the volume control of the hearing aid was adjusted so as to match the reference gain displayed on the screen. Thus the Reference Test Gain (RTG) was measured. Then by pressing the "Continue" button the test was proceeded and the values of frequency limit, Fl and F2, Harmonic distortion at 500Hz, Harmonic distortion at 1 KHz, Harmonic distortion at 1.6KHz, differential frequency distortion at 1.6KHz, Equivalent input noise and current drain were obtained.

Condition-II:

The measurements were done in the same way as done for the above condition but the connections in the hearing aid test box were different. Here the hearing aid was connected to the earmold which was connected to a 2cc coupler (HAl) by means of a clay (Funtak). The microphone was connected to the 2 cc coupler (HAl).

Condition-Ill:

The same measurements were done here also but the damper was inserted into the tubing of the earmold in addition to the connections mentioned in the condition-II. This was done by using a different dampers specifications of which were mentioned earlier.

This was done for 10 different Behind-the-Ear hearing aids. The electroacoustic characteristics thus meausred are defined in Appendix-B.

RESULTS AND DISCUSSION

The purpose of the study was to compare the effect and effectiveness of different imported dampers on electroacustic characteristics of Behind-the-Ear hearing aids. As mentioned in the previous section fourteen electroacoustic characteristics were measured for eleven conditions which included no earmold condition, with earmold but nodamper condition and nine conditions comprising of nine different dampers inserted into the earmold. The data was tabulated for each electroacoustic characteristic, for ten hearing aids and eleven conditions.

On subjecting these fourteen electroacoustic parameters, to ANOVA (Analysis of variance), it was found that seven parameters were significant at 0.01 level while other seven parameters were not significant. The Table- 2 indicates the results of ANOVA.

Parameters significant	Parameters not significant
1. OSPL 90 (Max)	1. Reference Test Gain
2. OSPL 90 (HFA)	2. Use Gain
3. HFA FOG	3. Harmonic Distortion at 500 Hz
4. Frequency Limit	4. Fl
5. Harmonic Distortion at 1KHz	5. F2
6. Harmonic Distortion at 1.6K	6. Equivalent Input Noise
7. Differential Frequency Distortion	7. Current Drain

TABLE 2: Indicating significant and non-significant parameters.

This indicates that the electroacoustic characteristics Reference test gain, use gain, harmonic distortion at 500Hz, Fl, F2, equivalent input noise and current drain are independent of the dampers.

Effectiveness of the dampers were determined by using the mean and the t-test scores. The findings are depicted in the Table-3. In this table the conditions comprising of the dampers inserted into the earmold system have been arranged in a hierarchial manner with ' the rating I indicating the most effectiveness.

Rating	OSPL 90 (Max)	OSPL 90 (HFA)	HFA FOG	Frequency Limit	H.D. at 1KHz	H.D. at 1.6KHz	D.F.D. at 1.6KHz
I	R1	R1	R1	R1	W1, G1, O1, G2, Y1, Y2, GR1, BR1, R1.	W1, G1, O1, G2, Y1, Y2, GR1, BR1, R1.	W1, G1, O1, G2, Y1, Y2, GR1, BR1, R1.
II	BR1*	GR1,BR1,Y1,Y2	GR1*	BR1*			
III	Y1, Y2, GR1	O1	Y1,Y2,BR1	Y1,Y2,GR1	No significant difference in T-test for the mean values	No significant difference in T-test for the mean values	No significant difference in T-test for the mean values
IV	O1, G2	G2	O1, G2	O1, G2			
V	G1	G1	G1	G1			
VI	W1	W1	W1	W1			

Table 3. Showing the order of effectiveness of dampers.

The effectiveness determined in terms OSPL . 90(Max) (refer OSPL 90 Max column of Table-3.) correlated with the acoustic resistance or attenuation in dB values of the dampers. However, the effeciveness of dampers Orange (01) and Green (G2) were found to be same as, no significant difference was found between their means from the t-test scores. Similarly dampers yellow (Yl), Yellow (Y2) and Grey (GRl) were found to be the same in effectiveness. In the table, BRl is indicated by Asterick (*) because it was significantly different only at 0.05 level(Table-F).

For OSPL 90(HFA), it was determined that the effectiveness of dampers again correlated with the acoustic resistance or attenuation in dB values of the dampers. (For order of effectiveness refer OSPL 90(HFA) column of table-3). Here it was found that though there was a difference in the mean values of dampers Yellow (Yl), Yellow (Y2), Brown (BRl) and Grey (GRl), t-test showed no significant difference between them. Hence these four dampers were grouped together implying that they were equal in effectiveness.

The HFA FOG parameter had the order of effectiveness for dampers which also correlated with the acoustic resistance and attenuation in dB values of the dampers. (Refer to HFA FOG column of TAble-3). Here it was found that, though a mean difference existed between the values obtained by using Orange (01) and Green (G2), no significant difference was found in t-test scores. Hence 01 and G2 were found to be equally effective. Similarly Yellow (Yl), Yellow (Y2) and Brown (BRl) were found to be equally • effective. The damper Grey(GRl)(marked with asterick in Table-3) was found to be signifincantly different only at 0.05 level.

The paramter frequency limit had the order of effectiveness for dampers which also correlated with the acoustic resistance or attenuation in dB value of the dampers. (Refer to FL column of Table-3). Though a mean difference existed between dampers Orange (01) and Green (G2), they were not found to be significantly different from the t-test scores. Hence they were grouped together. Similarly dampers Yellow (Yl), Yellow(Y2), and Grey(GRl) were said to be equally effective and grouped together. Damper Brown(BRl) was found to be signifcantly different only at 0.05 level and hence is marked by an asterick (*) in the Table-3.

In all these parameters Red(Rl) damper had maximum effectiveness and White (Wl) had the least effectiveness, i.e. Red(Rl) damper offers maximum damping while White(Wl) offers least damping among the dampers used.

The analysis of the other parameters i.e. Harmonic distortion at 1 KHz, Harmonic distortion at 1.6 KHz, and differential frequency distortion at 1.6 KHz, showed no significant difference in t-test, with change in damper values. This is because these parameters are dependent on the electronic circuitry and not on the acoustic impedence. Hence we can conclude that the parameters such as distortion at various frequencies and differential frequency distortions are independent of the dampers used. (These are also indicated in the last 3 columns of Table-3).

When the hearing aid with no earmold condition and the hearing aid with earmold condition were compared, it was found that there was no significant difference between them, for all the four electroacoustic characteristics.

Thus we can conclude that the differences in the electroacoustic measurements that were obtained by using dampers were solely due to the dampers and not because of the combined effect of dampers and earmolds.

The present study has implications towards hearing aid prescription. Many a times an audiologist encounters problems in fitting hearing aids to severe hearing loss patients with tolerance problem. This is becuase inspite of achieving the gain required, the case has-discomfort due to tolerance problem. Though the recent hearing aids have facilities for special electornic ciruitry like automatic gain control, peak clipping, etc. they have certain limitations. A part of the signal is lost in peak clipping which leads to distortion. In automatic gain control, owing to the rapid attack time and release time, clicks and flutters are superimposed on the acoustic signal. In addition, this is an expensive option. On the other hand, dampers are relatively less expensive. As they reduce the peak of SSPL90 curve, the user can increase the volume control setting, thereby making use of the gain the hearing aid has to offer at other frequencies, especially in the high frequency region. Again the maximum power output can be set at a higher level. This allows the user to have slightly higher gain without encountering the problem of tolerance. This is in agreement with Chasin's(1983) study.

The rating of damper showed that Red(Rl) damper was most effective while White(Wl) was least effective with other dampers rated in between in the order of effectiveness. This also has clinical implication in terms of selection of appropriate dampers for inserting into the tubing of the earmold for a particular patient.

SUMMARY AND CONCLUSION:

The aim of the present study was to compare the effect and effectiveness of different imported dampers on the electroacoustic characteristics of Behind-the-Ear hearing aids.

Electroacoustic measurements were made for ten Behind-the-Ear hearing aids, each connected to nine different dampers. These measurements were compared with the electroacoustic characteristics of ten hearing aids with and without earmolds. The data obtained was subjected to appropriate statistical analysis.

Results showed significant difference between dampers used, for OSPL 90(Max), OSPL 90(HFA), HFA-FOG and frequency limit. The order of effectiveness of dampers for each electroacoustic characteristics were also obtained (Table-3). It was found that the red(Rl) damper had the greatest damping effect and White (Wl) had the least damping effect for all parameters. The clinical implications of the findings are interms of hearing aid fitting.

Recommendations for further study:

(1) Electroacoustic characteristics can be measured for these dampers. When placed at different positions along the earmold.

(2) A study ofthe effect of these dampers on the OSPL 90 and frequency response curves can be made.

(3) A study can be carried out by using these dampers on subjects making use of "Insertion Gain Optimiser - Hearing Aid Trial" system.

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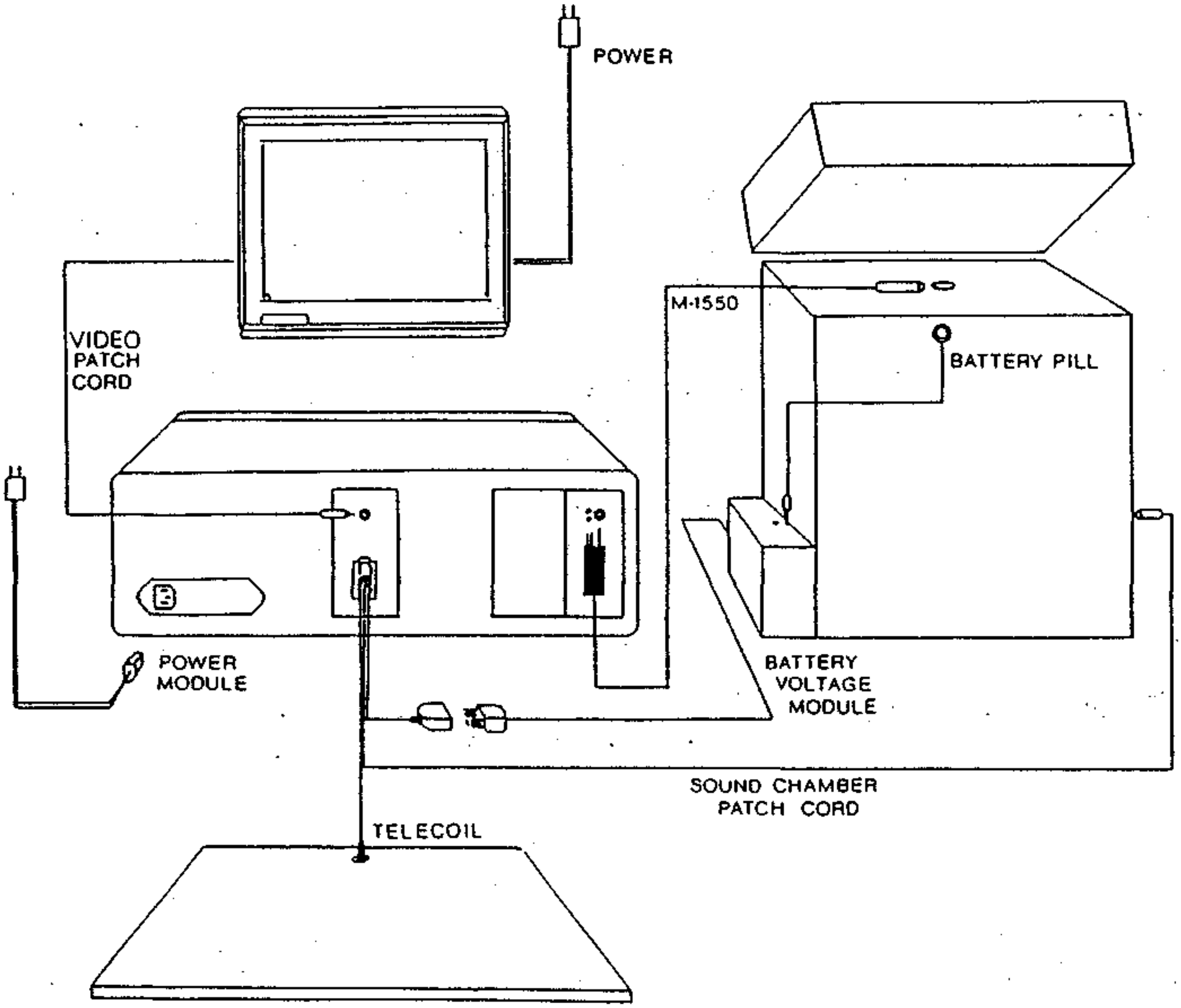
Manual for the hearing aid test system (FONIX 6500)

Manual for the products of the HAL-HEN Company Inc.

APPENDIX - A


POWER
VIDEO PATCH CORD
M-1550
BATTERY PILL
POWER MODULE
BATTERY VOLTAGE MODULE
SOUND CHAMBER PATCH CORD
TELECOIL

APPENDIX-B

SATURATION SPL (OSPL 90): It is important to know at what level a hearing aid limits its output when it receives a high level input signal. It is defined as the SPL developed in a 2cc earphone coupler when the input SPL is 90dB and the gain control of the hearing aid is full-on.

High Frequency Average SSPL-90 (HFA-SSPL 90): is defined as the average of 1000, 1600 and 2500 Hz SSPL 90 values.

High Frequency Average Full-On-Gain (HFA-HOG): is defined the average of 1000, 1600 and 2500Hz SSPL 90 values when the input SPL is 60 dB and the gain control of the hearing aid is full on.

Reference Test Gain (RTG): This gain setting is established, using an input sound pressure level of 60dB, by adjusting the gain control so that the average of the 1000, 1600 and 2500 Hz gain values are equal to the HF-average SSPL-90 minus +/- ldB.

Use Gain (UG): This is the gain of the hearing aid measured by setting the volume control at 1/3 of the maximum volume setting available for that hearing aid.

Frequency Range: The frequency range of an hearing aid refers to the useful range of the frequency response. It is expressed by two numbers, one representing the low frequency limit of amplification (fl) and the other, high frequency limit (f2) with both numbers expressed in Hz.

Total Harmonic Distortion: Harmonic distortion is a result, primarily, of overloading the hearing aid amplifier or earphone. It occurs when the instantanious output sound pressure of the hearing aid earphone is not directly propotional to the instantaneous sound pressure at the microphone. Measured at 500 Hz, Hz lOOOHz, 1600Hz.

DF. Distortion at 1KHz (Intermodulation distortion): This occurs when the output signal contains frequencies that are arithmetic sums and differences of two or more input frequencies. When two or more frequencies (as in speech) are applied simultaneously at the input, it is the result of amplifier nonlinearity.

Equivalent Input Noise Level (EIN): This particular characteristic relates to the magnitude of internal noise generated by the hearing aid.

Current Drain: With the gain control in the reference test position, measure the battery current with a pure tone of 1000 Hz as input, at a sound pressure level of 65 dB.

APPENDIX-C

The dampers used in this study are available at :

Hal Hen Company Inc.
35-53, 24th Street
Long Island City
NEW YORK 11106

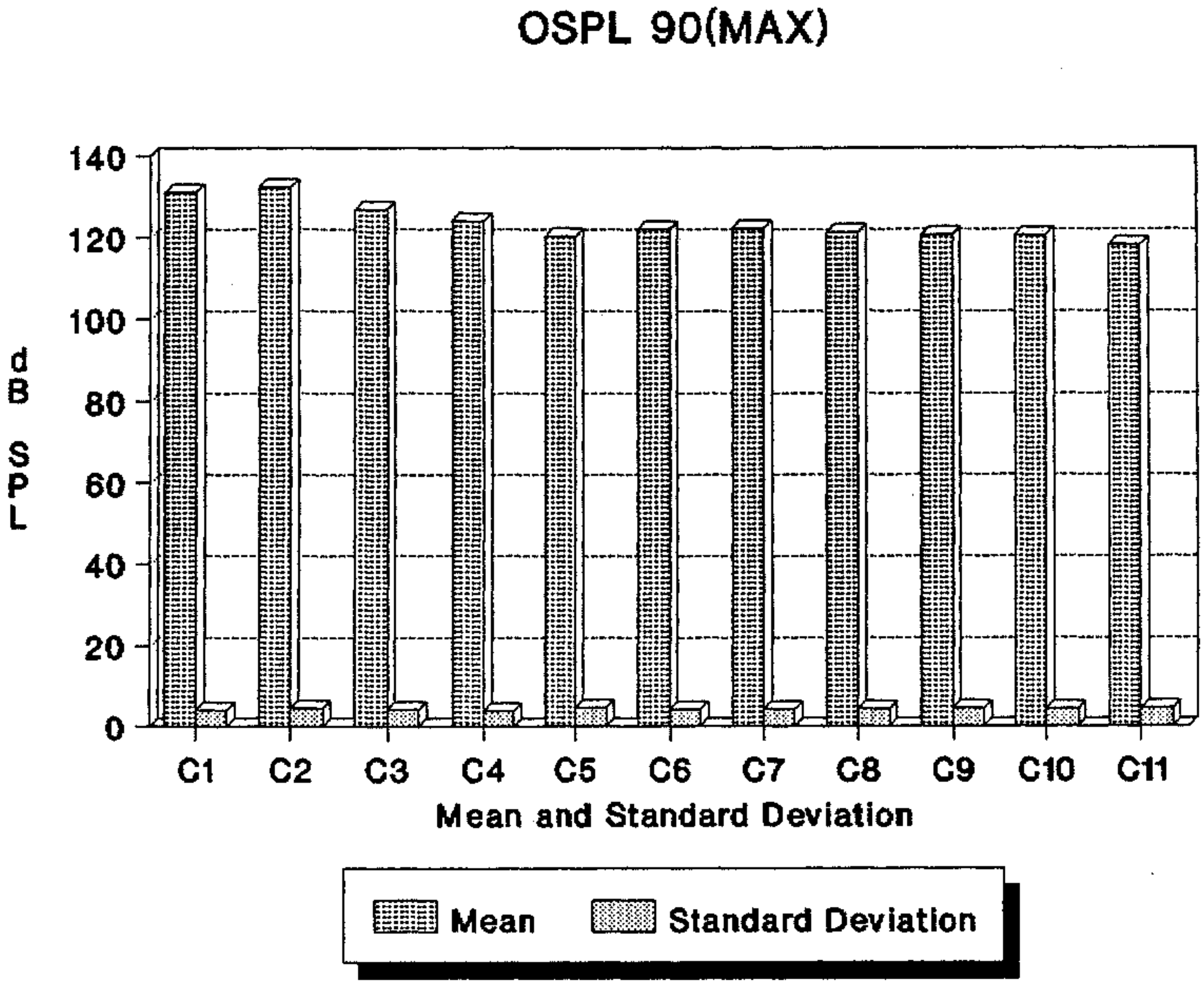
(718)392-6020
Telex:667959

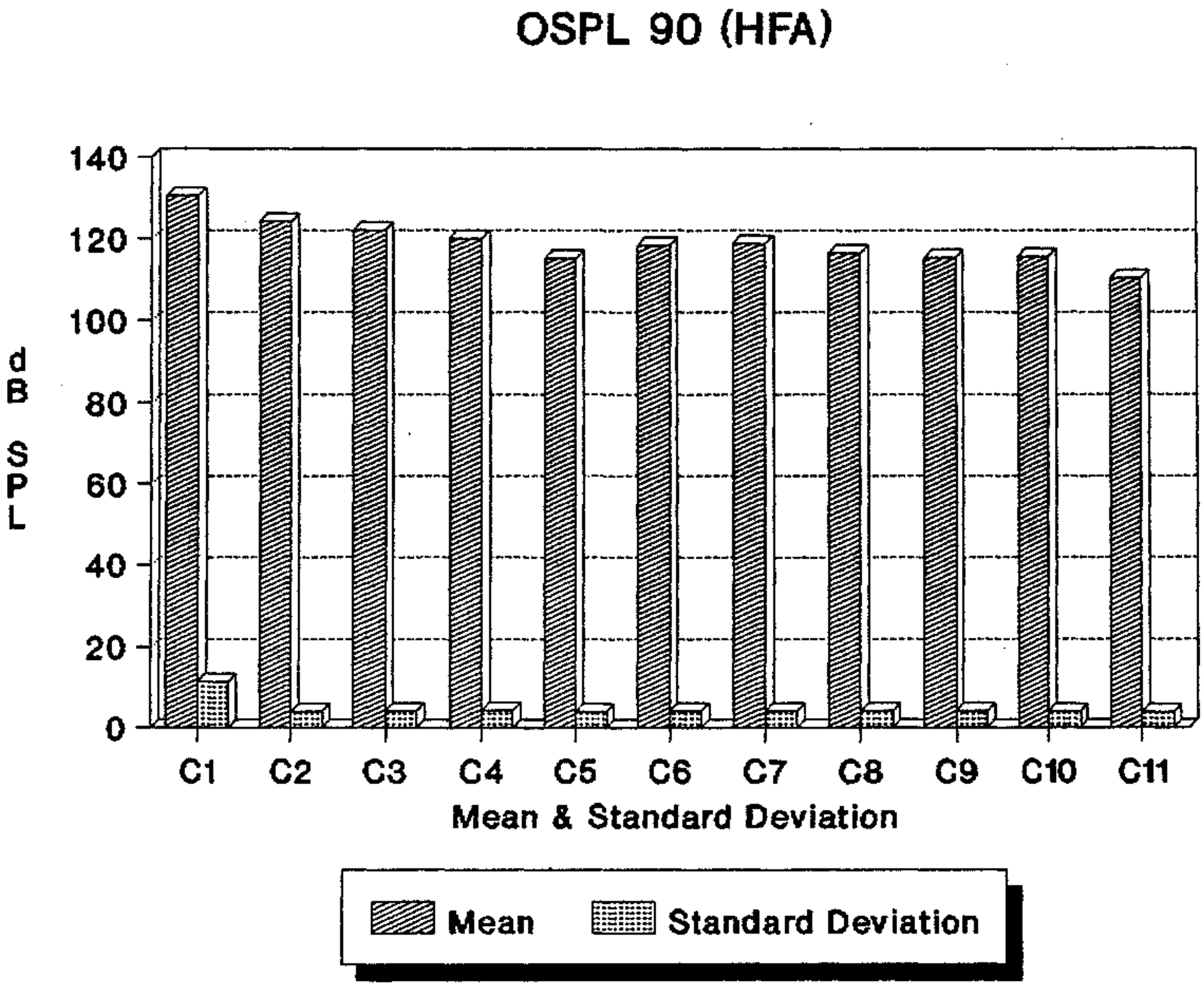
The cost of these dampers as on 27.11.1989 are as follows:

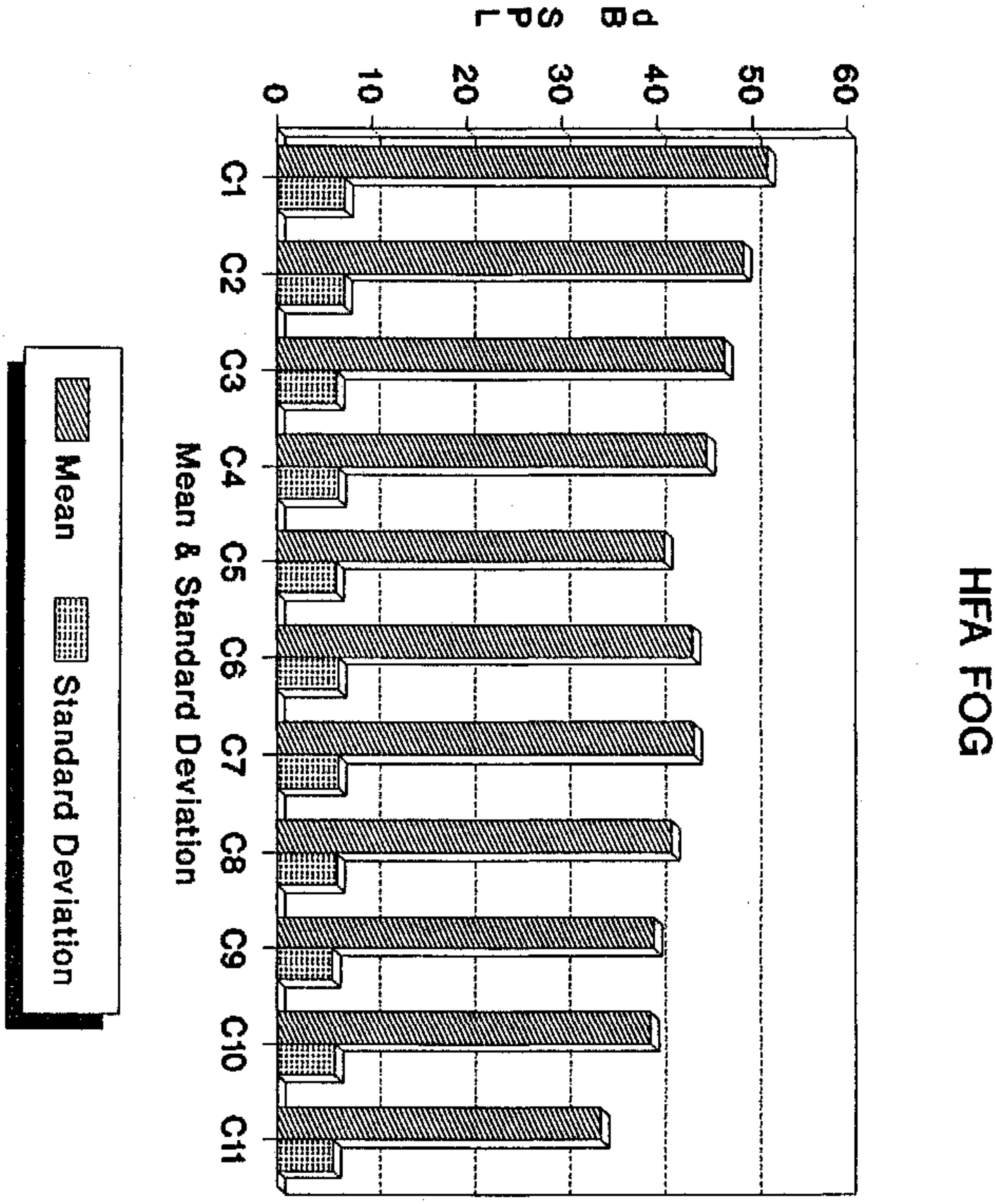
#2394	**Knowles acoustic dampers** **Each package - 10 dampers**	**$9.50 per pkg.**
#2129	**Attenuators** **Each kit-7 types 5 each**	**$29.00 per kit**

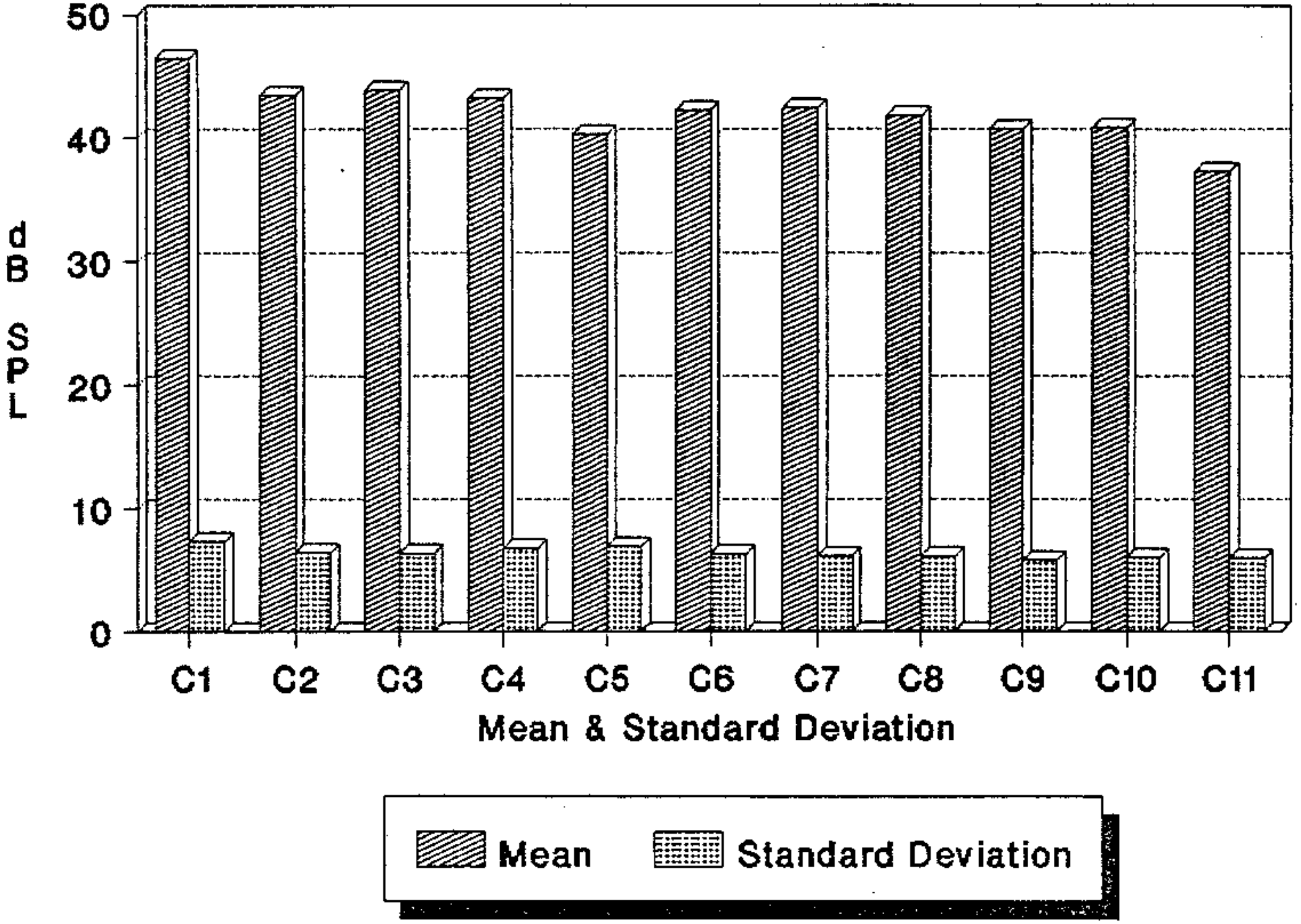
The following pages contains the graphical representation of the Mean and Standard Deviation with X-axis showing different conditions and Y-axis showing the dB SPL values.

The conditions are named Cl to Cll where
Cl = No earmold condition
C2 = With earmold but no damper condition
C3 = With earmold and damper Wl
C4 = With earmold and damper W2
C5 = With earmold and damper Yl
C6 = With earmold and damper 01
C7 = With earmold and damper G2
C8 = With earmold and damper BRl
C9 = With earmold and damper Y2
C1O = With earmold and damper GRl
Cll = With earmold and damper Rl

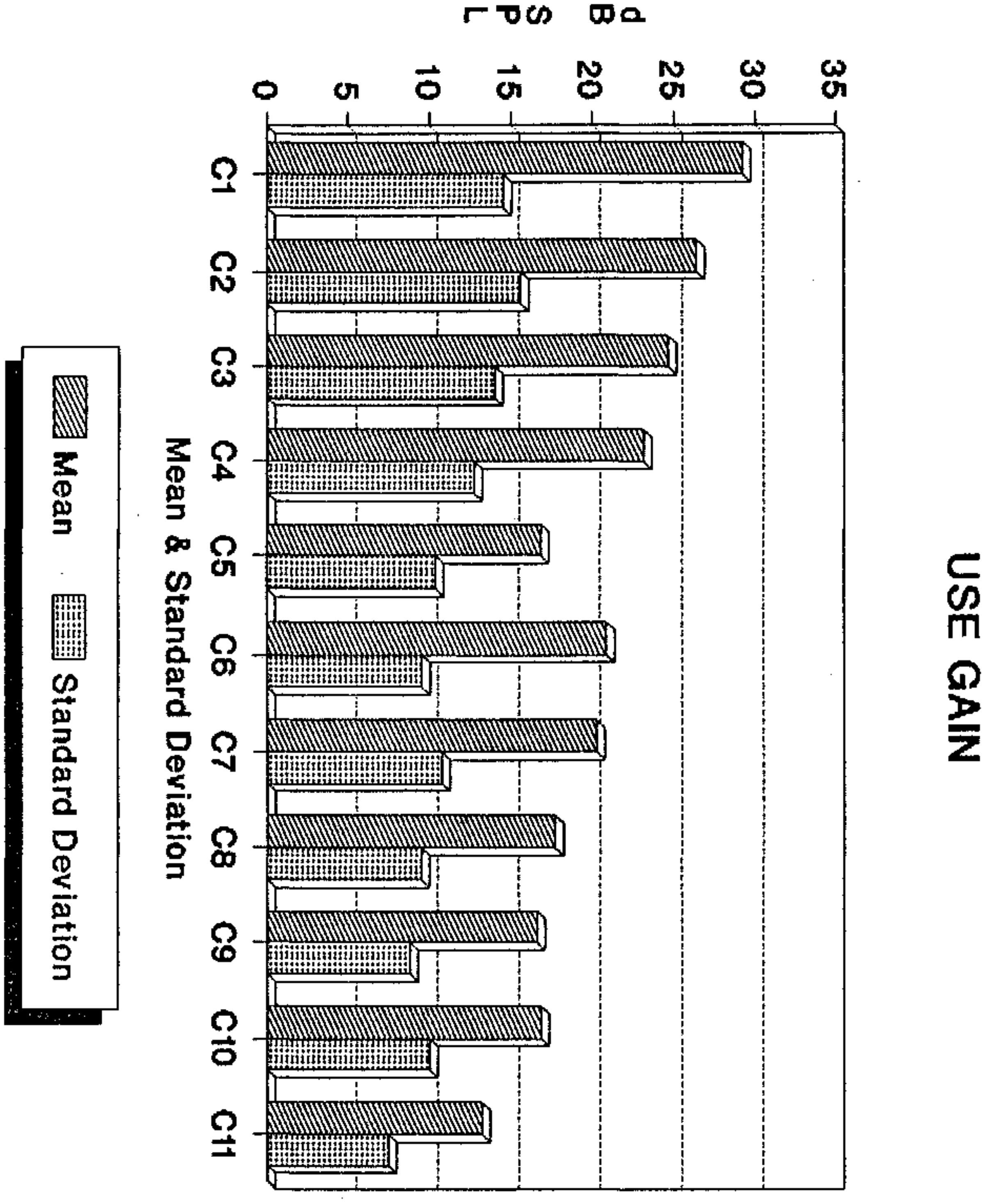

OSPL 90(MAX)
dB SPL
0
20
40
60
80
100
120
140
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
Mean and Standard Deviation
Mean
Standard Deviation

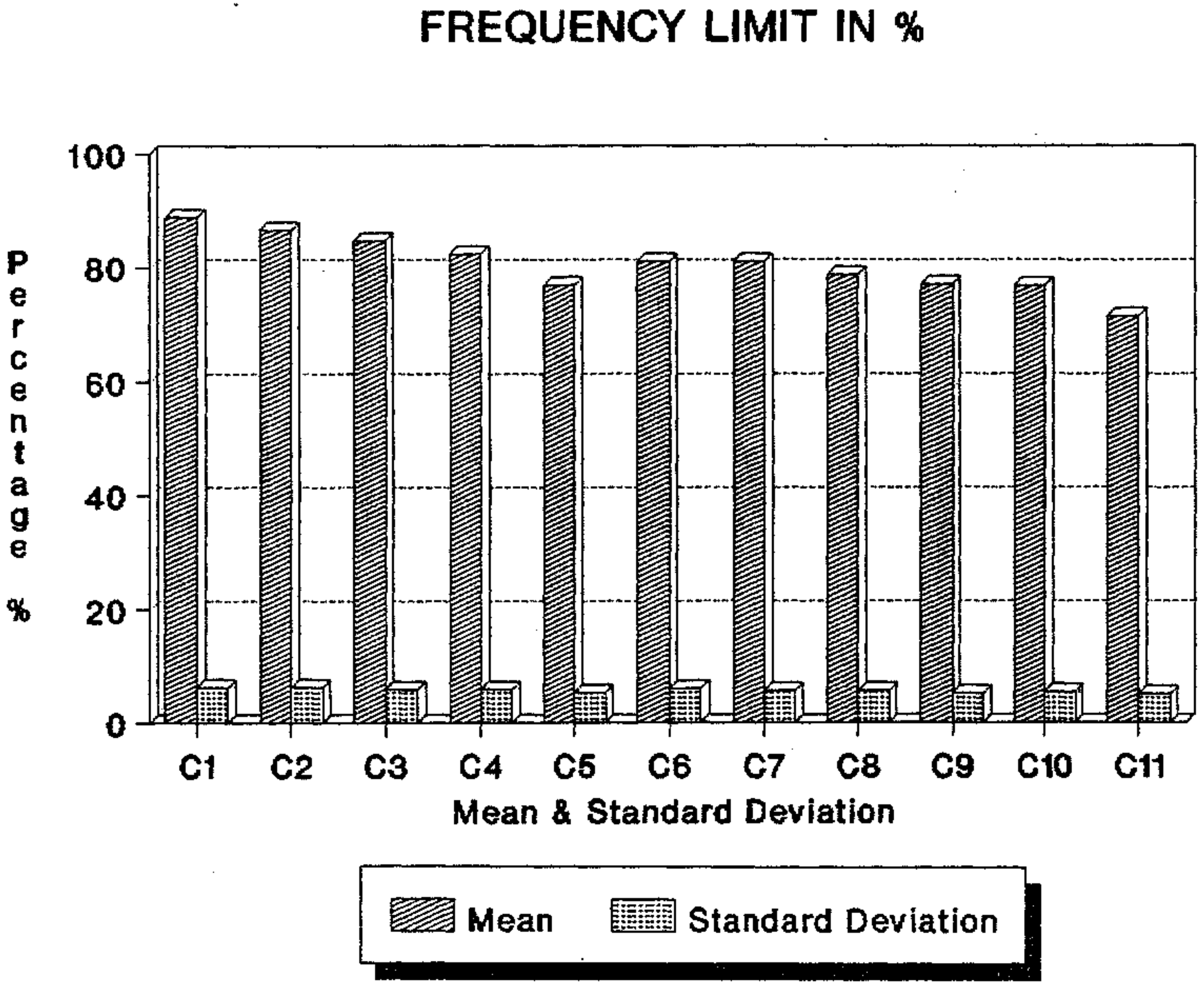

OSPL 90 (HFA)
dB SPL
140
120
100
80
60
40
20
0
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
Mean & Standard Deviation
Mean
Standard Deviation


HFA FOG
d
B
S
P
L
0
10
20
30
40
50
60
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
Mean & Standard Deviation
Mean
Standard Deviation

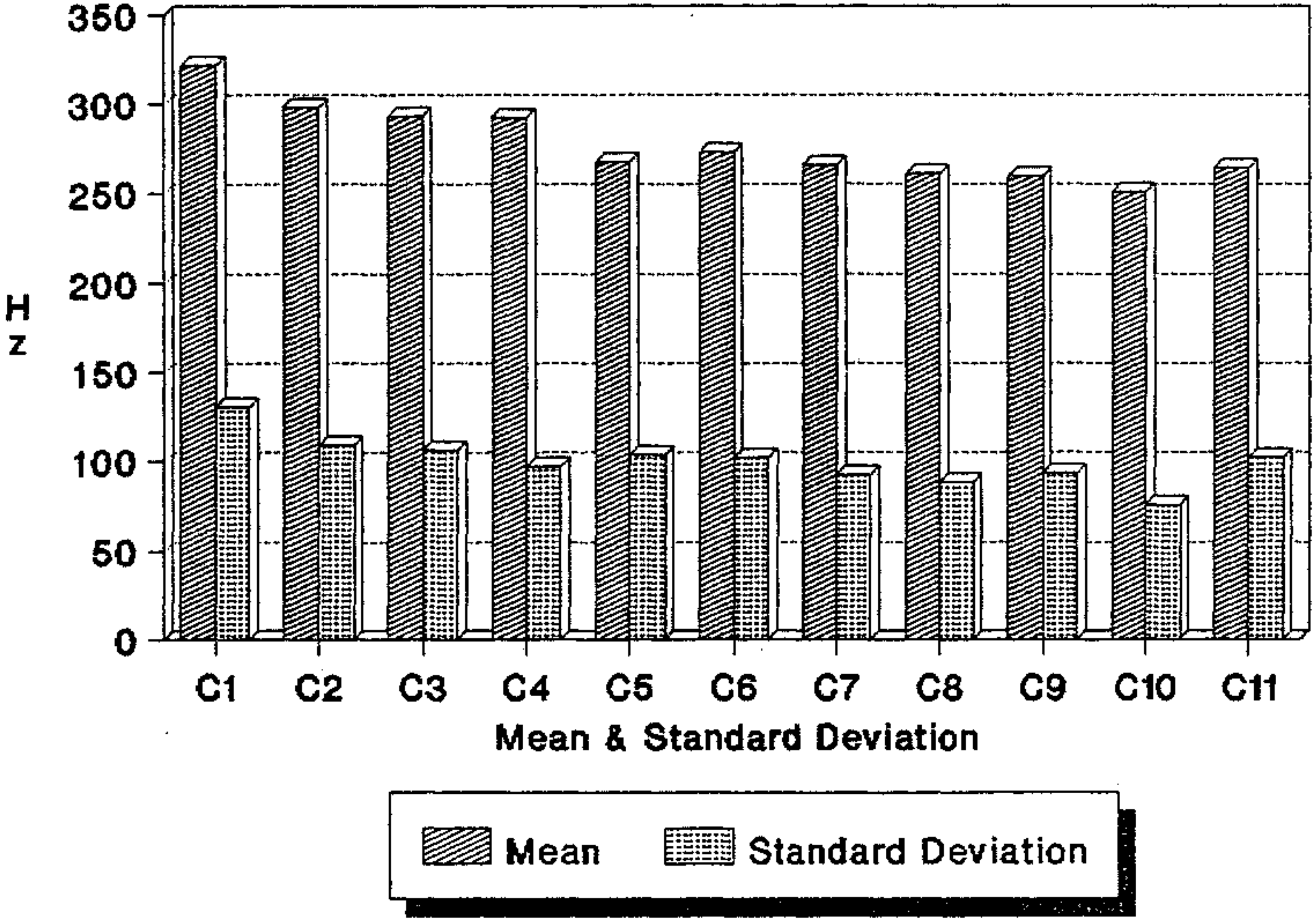


REFERENCE TEST GAIN

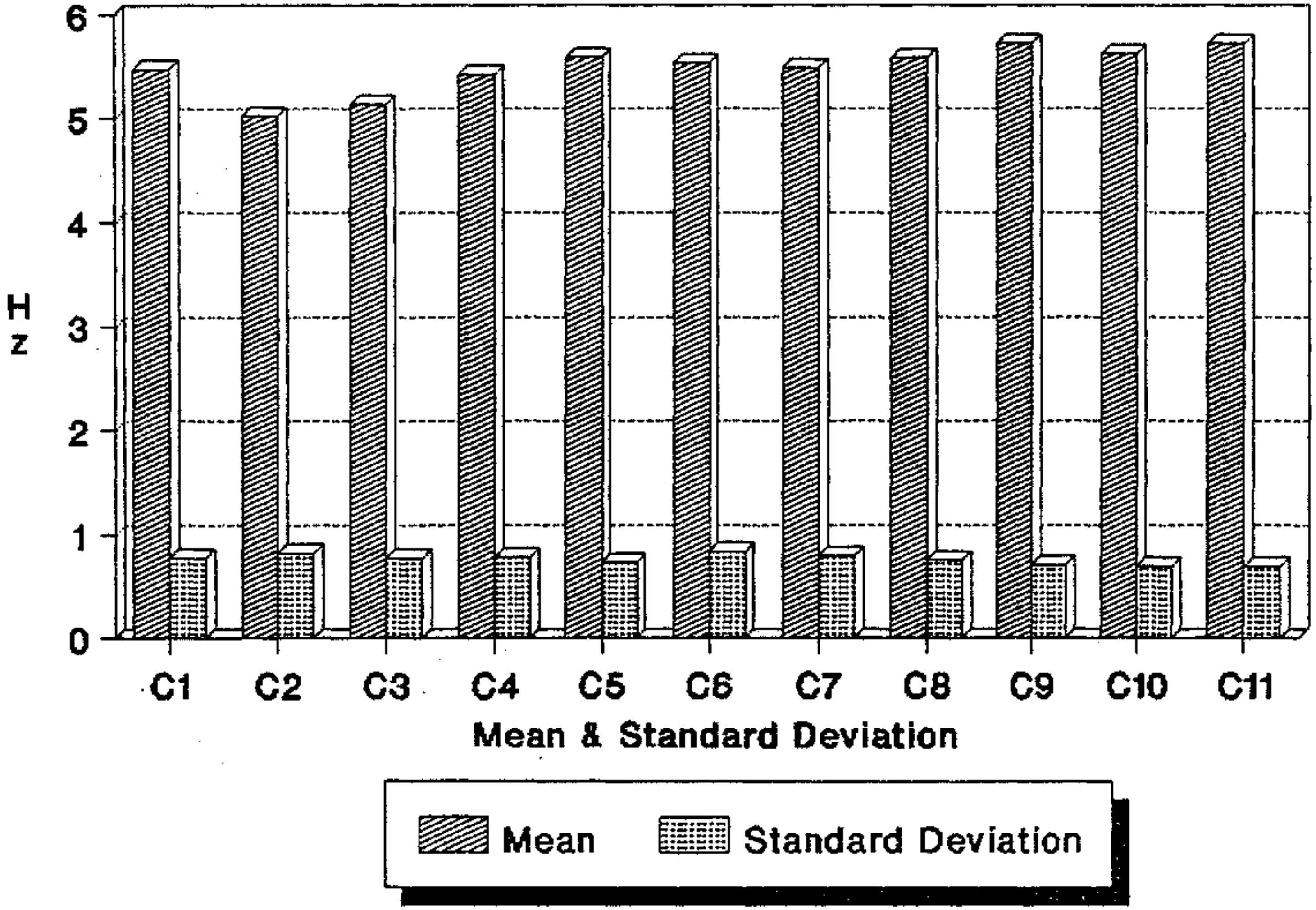

USE GAIN
dB SPL
0
5
10
15
20
25
30
35
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
Mean & Standard Deviation
Mean
Standard Deviation


FREQUENCY LIMIT IN %
Percentage %
0
20
40
60
80
100
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
Mean & Standard Deviation
▨ Mean
▦ Standard Deviation

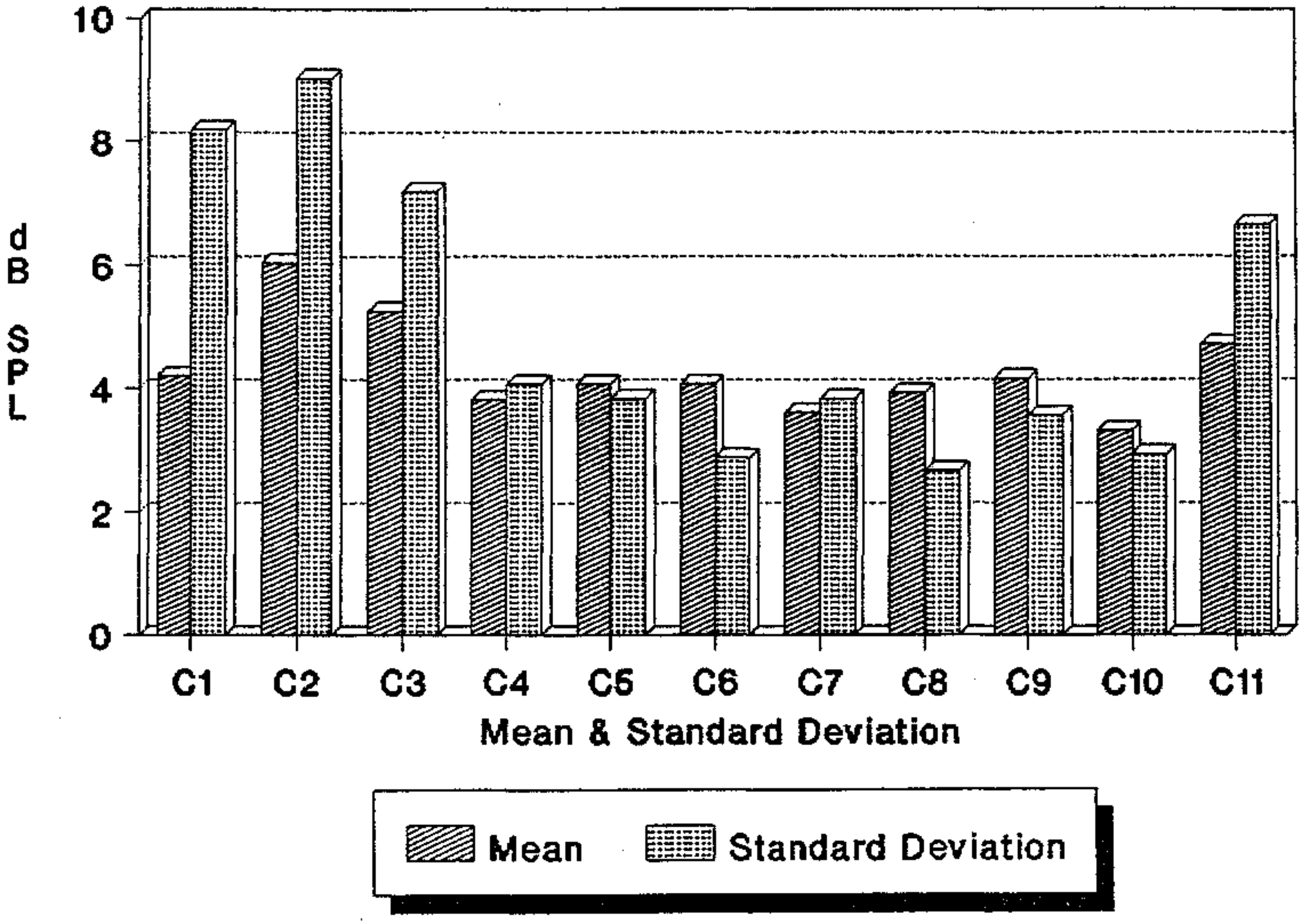
F1


350
300
250
200
150
100
50
0
Hz
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
Mean & Standard Deviation
▨ Mean
▦ Standard Deviation

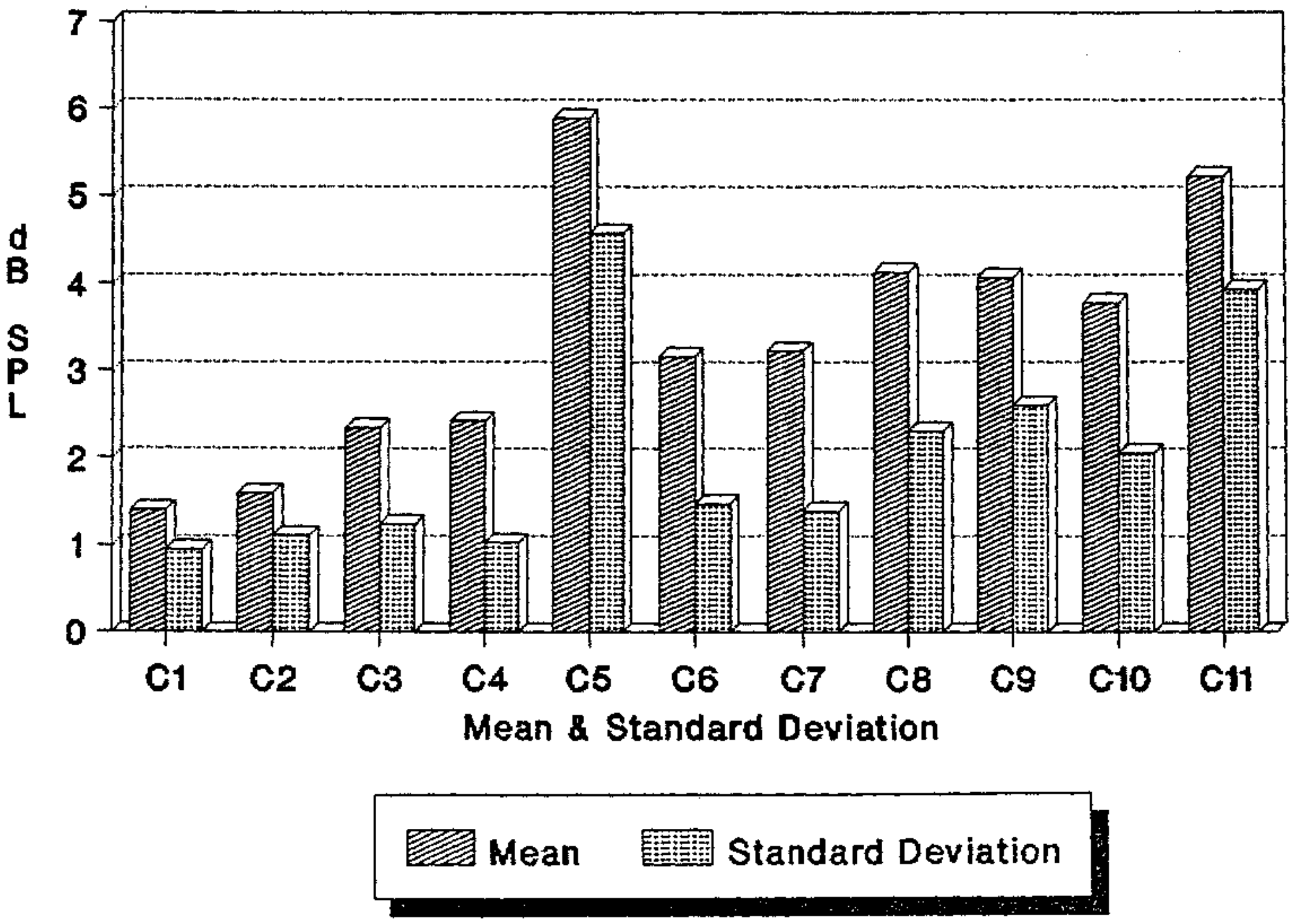
F2

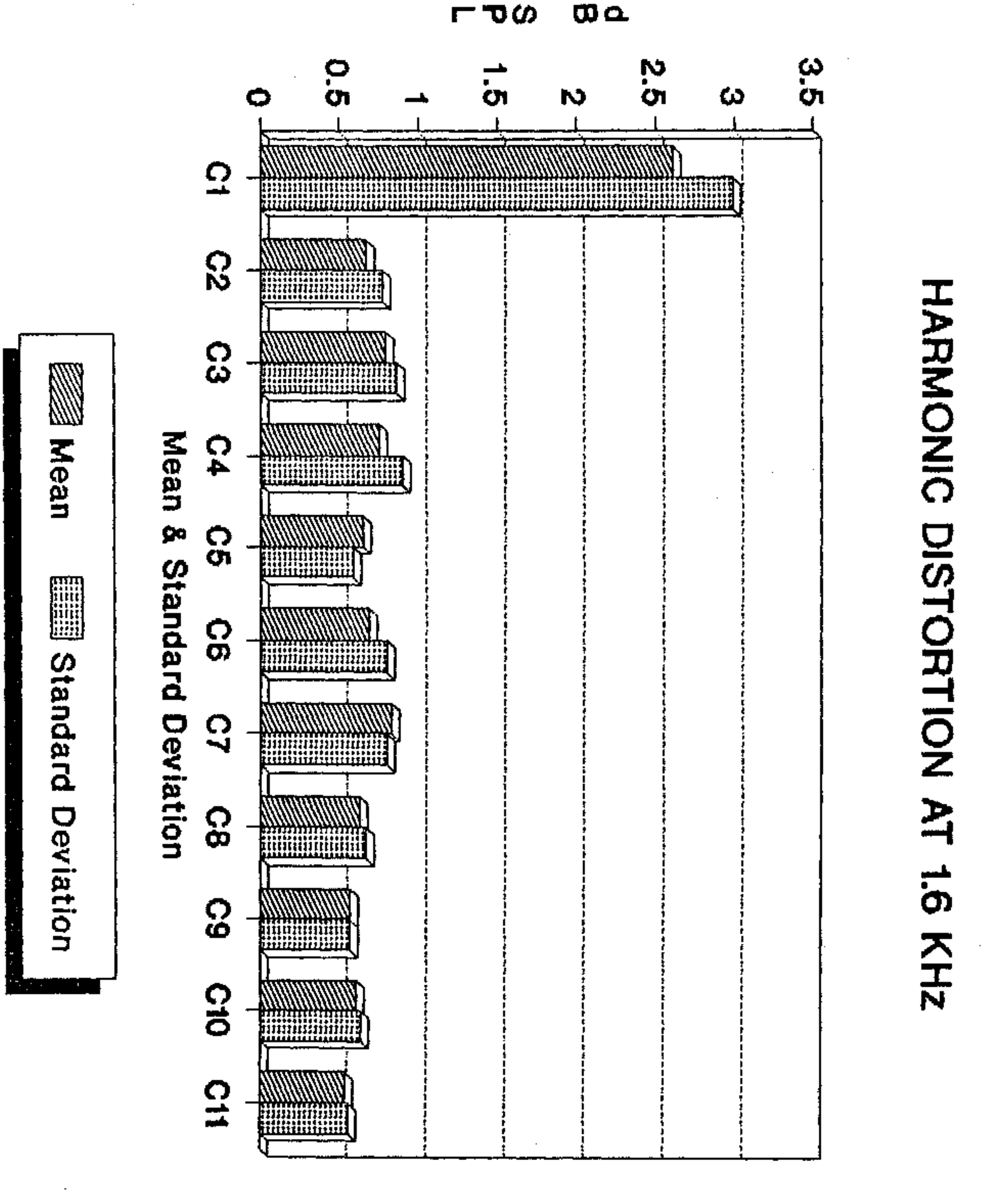

6
5
4
3
2
1
0
Hz
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
Mean & Standard Deviation
Mean
Standard Deviation

HARMONIC DISTORTION AT 500 Hz

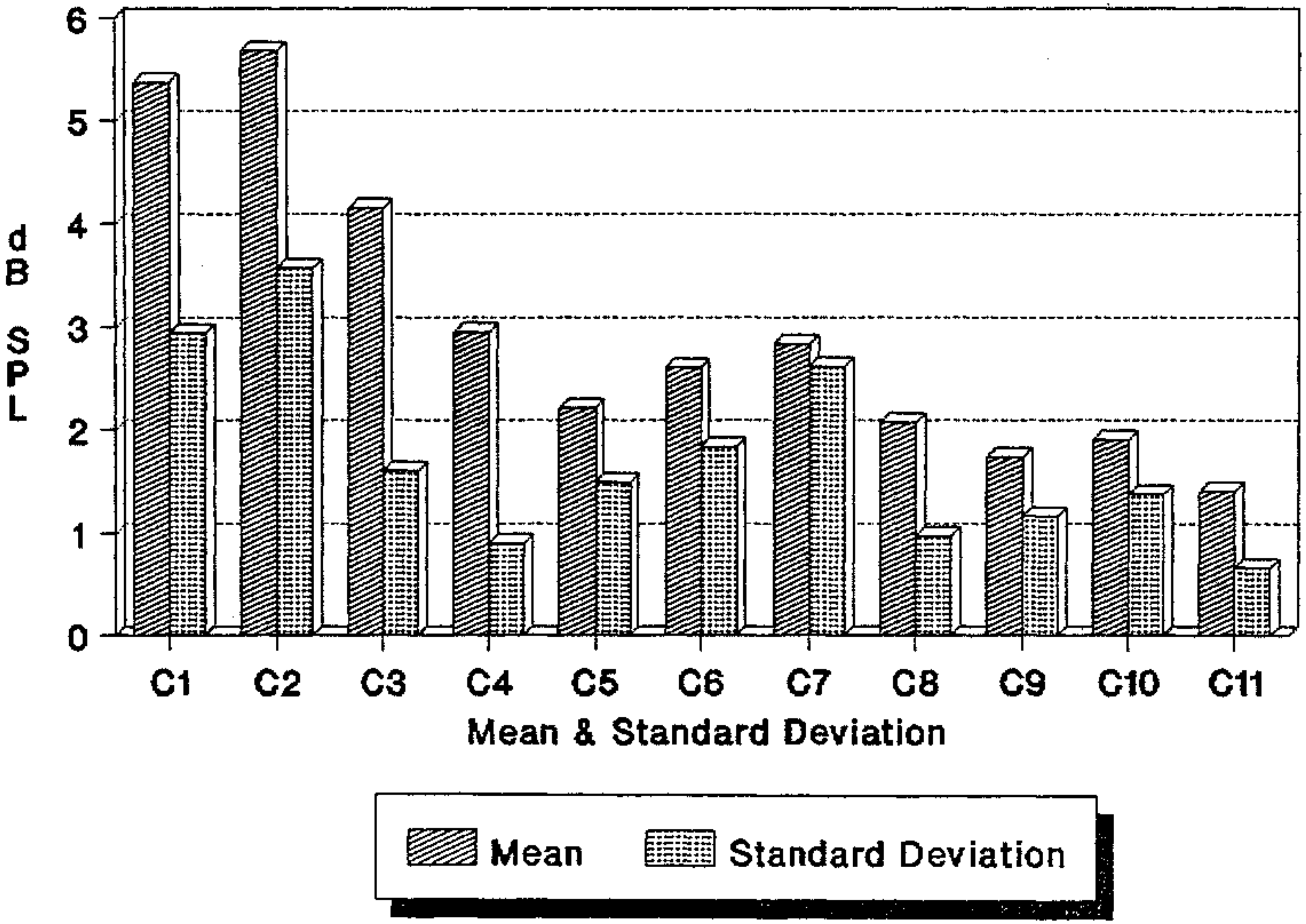


HARMONIC DISTORTION AT 1 KHz

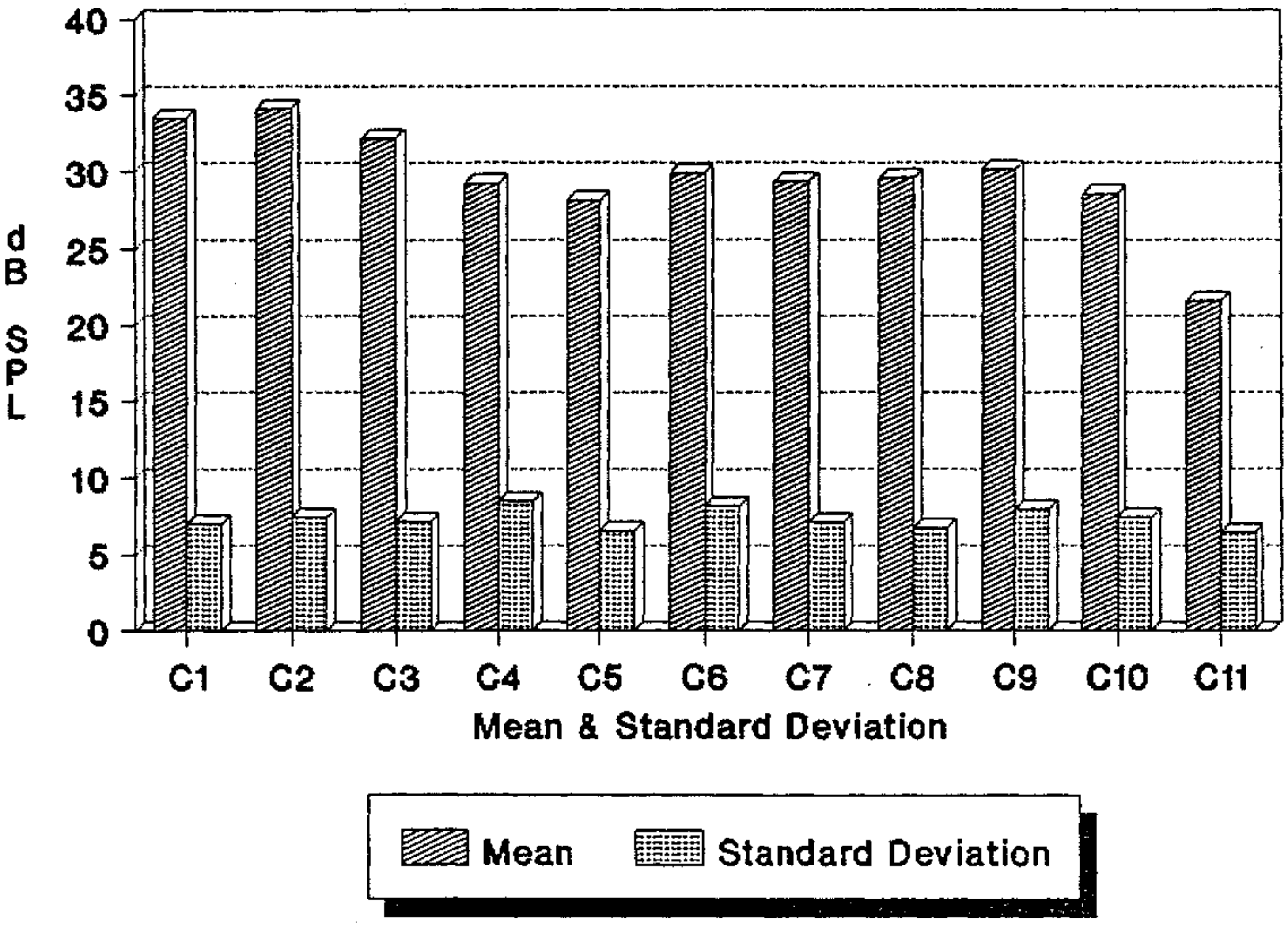


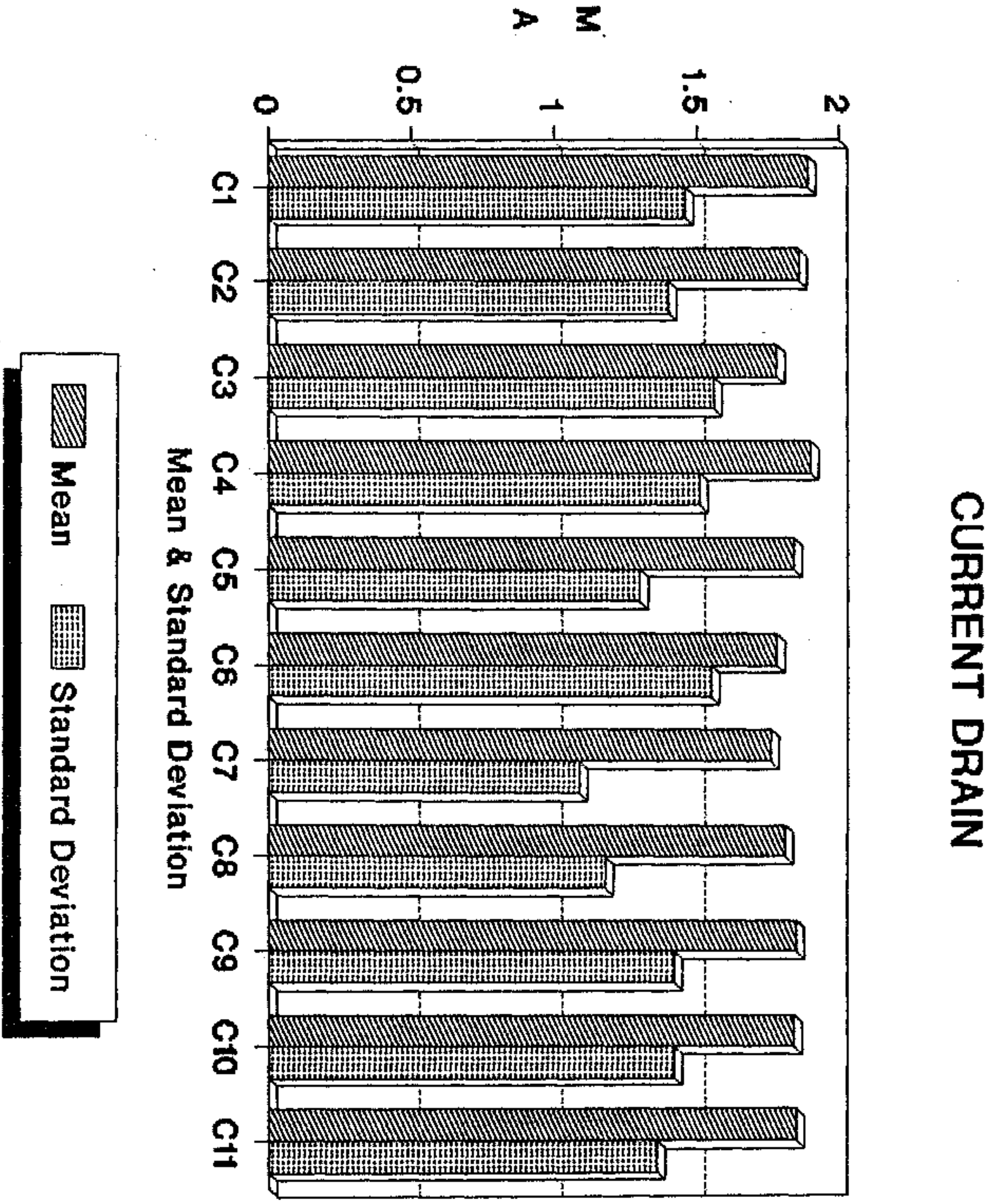

HARMONIC DISTORTION AT 1.6 KHz
d B S P L
0
0.5
1
1.5
2
2.5
3
3.5
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
Mean & Standard Deviation
▨ Mean
▦ Standard Deviation

D.F. DISTORTION AT 1 KHz



EQUIVALENT INPUT NOISE




CURRENT DRAIN
M
A
0
0.5
1
1.5
2
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
Mean & Standard Deviation
▨ Mean
▦ Standard Deviation