THE EFFECT OF INDIGENOUSLY MADE DANPERS ON THE ELECTROACOUSTIC CHARACTERISTICS OF BEHIND THE EAR HEARING AIDS

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1992

Dedicated to

Amma, Appa, Akka

CERTIFICATE

This is to certify that the Independent Project entitled: **THE EFFECT OF INDIGENOUSLY MADE DAMPERS ON THE ELECTROACOUSTIC CHARACTERISTICS OF BEHIND THE EAR HEARING AIDS** is the bonafide work in part fulfillment for M.Sc., in speech and Hearing of the student with Reg. No. M 9103.

Director
All India Institute of
Speech and Hearing, Mysore.

Mysore
1992

CERTIFICATE

This is to certify that the Independent Project entitled: **THE EFFECT OF INDIGENOUSLY MADE DAMPERS ON THE ELECTROACOUSTIC CHARACTERISTICS OF BEHIND THE EAR HEARING AIDS** has been prepared under my supervision and guidance.

Mysore	Dr. (Miss) S. Nikam,
1992	GUIDE

DECLARATION

This Independent Project entitled: **THE EFFECT OF INDIGENOUSLY MADE DAMPERS ON THE ELECTROACOUSTIC CHARACTERISTICS OF BEHIND THE EAR HEARING AIDS** is the result of my own study undertaken under the guidance of Dr. (Miss) S. Nikam, Prof. and Head of the Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other Diploma or Degree.

Mysore
1992 Reg. No. M. 9103

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PROLOGUE

It is common knowledge that hearing aids help persons with impairment of hearing to regain certain amount of normalcy in the faculty of hearing. The hearing aids are manufactured to suit the needs of subjects after this are subjected to extensive tests designed to determine the extent of their impairment and consequential required assistance.

Technological advancement in the field of amplification system has seen drastic improvements in responses and sound quality of hearing aids over recent years, and further improvements can still be made by modifying the sound channel from the hearing aid to the tympanic membrane. These techniques involving the principles of acoustic have been known to science 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 philosophical considerations. They are -

a) To preserve the balance acoustically between the high and low frequencies in normal speech spectrum.
b) To preserve the normal eardrum – freefiled transfer.
c) To extend the high frequencies in wearable hearing aids.
d) To minimize and/or elevate the standard peak in hearing aid responses at 1000-1500 Hz for many mild and moderate losses.

e) To gradually slant upwards the frequency responses of an aid.
f) To keep the output of an aid within the client's dynamic range.

These are accomplished by adjusting the frequency response of hearing aid with special attenuation to the earmold and associated plumbing. Individual adjustments to low, middle and high frequencies with use of venting, damping and horn effects respectively can be made.

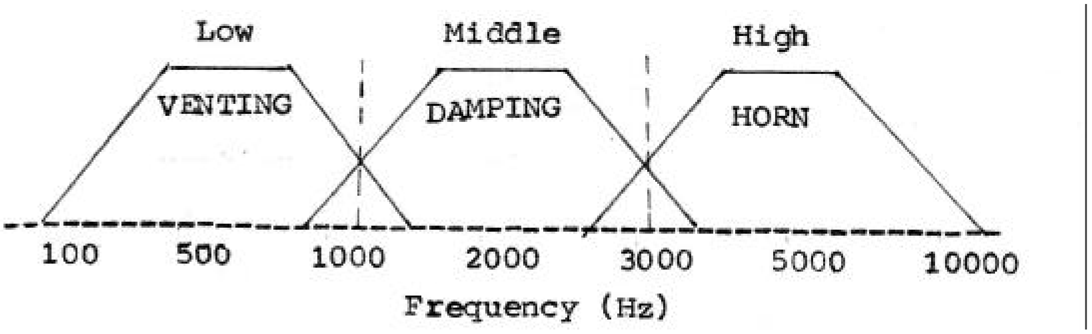


Fig.1: Earmold modification and frequency of influence

I. Venting:

Earmold venting appears to have been used Ist 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 which is an intentionally produced leak (Langford, 1975) cited by Pollack (1975).

Purposes:

1. Barometric equalization
2. Eliminates blocked up feeling in the ear

3. Ventillates ear canal, alleviates discomfort, heat and humidity.
4. Reduces occlusion by earmold.
5. Improves sensitivity.
6. Radical modification of frequency response – low-frequency reduction.

II. Horn effects – Acoustic horn:

Killion and Knowles (1978)*, Killion (1981)*, Brunved (1985)* report of the use of acoustic horn principle in hearing aid response modification. Acoustic horn as defined by Brunved (1985)* is “a tube of varying C-S having different terminal areas that provide a change of acoustic impedance”. In hearing aids, the horn provides a better acoustic impedance of hearing aid tubing and the relative low impedance of the ear canal.

The effectiveness of a horn is governed by specific acoustic laws with regard to the physical dimensions of the horn.

Types of acoustic horn are - Libby horn, Bakke horn, Exponential horn, Killion horn, reverse horn.

III. Acoustic damping:

Tubing resonance and a helmhotz resonance (produced by the acoustic compliance of the air cavity in front of the hearing aid receive) causes sharp peak and 1000Hz in the output of

BTE aids as measured in 2 cc couplers and around 2000Hz or higher for ITE aids (Skinner, 1988)*. These can be excited by sharp transient sounds, causing a “ringing” sound as “echoing” sound. Various acoustic resistance/damping elements have been used to smoothen the frequency response of the hearing aid – earmold system and to control gain and Saturn output.

The effects of acoustic dampers on hearing aid responses are determined by –

1. The value of the acoustic resistance, higher values causing more flattening of peak.
2. The number of dampers used.
3. The location of damper(s) in the acoustic transmission system (Lybarger, 1985).

A. Characteristics:

Killion (1977)*, Cox (1979) reported that an acoustic damping element could only dissipate energy when there was airflowing through the element. As the airflow through the element increases, the effectiveness of the damping element increases.

Cox (1979) pointed out that for wave length resonances the antinodes of the standing waves in a tube represents positions of maximum airflow, 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 elements at the antinode location of unwanted resonant frequencies.

The resonant frequencies of a tube open at one end is

$f = \underline{(2k-1)\ V/4L}$ where

V= Velocity of sd

L= effective length of earhook, tubing path and

K= mode of resistance.

Eg. If L= 75 mm, the Ist 3 modes of resonance and

$f_k=1=1100$ Hz

$f_k=2=3300$ Hz

$f_k=3=5500$ Hz

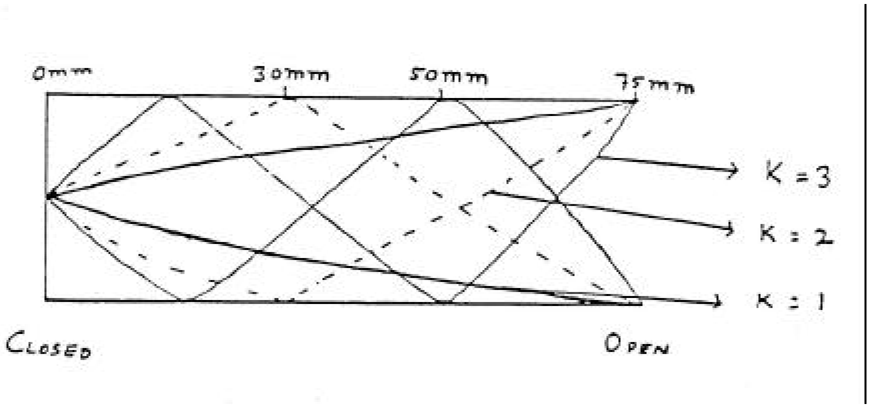


Fig.2:

Volume velocity of sound is greatest at a point where there is an antinode in standing wave pattern. Greater the volume velocity, the more effect will the acoustic resistance have ie. resistance will have little effect if placed at nodal position.

In figure, ear hook hub is 30 mm from the closed receiver end. Placement of the resistor here will have larger effect on damping 1100 Hz (K=1 curve) and lesser effect on damping 5500 Hz (K=3 curve). However, if resistance is inserted further down (at 25-30 mm) from end of bore; 1100 Hz is slightly damped and 5500 Hz is maximally damped, with 3300 Hz resonance intact (minimal damping).

The exact positioning of resistor in tubing is not clinically significant as long as it is within 5 mm of the target position.

Killion (1977)* reported that for damping to occur, the acoustic damping element should have a characteristic or surge impedance equal to that of the earmold tubing. A damping element that has a resistive value equal to the surge impedance will properly terminate a transmission line (ie. hearing aid) or ear mold tubing resulting in absorption of all incidental energy, thereby avoiding the reflections of energy which are basically responsible for the resonant peak.

B. Acoustic properties of damping elements:

a) Smoothening, the resonant peaks in the output of the amplification system.

b) This, in trun, reduces feeback problems which may be associated with sharp peaks in the output of the system (Killion, 1980)*.

c) Cox and Gillmore (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.

C. Types of dampers:

The resistive or damping elements used widely include the following:

(i) Lamb's wool (ii) Sintered filters.

(i) Lamb's wool:

Langford (1975) reported a method of damping where lambs wool is inserted in the tubing or mold of the coupler system. The degree to which the response changes when this is used is difficult to determine unless artificial ear is available, hence changing the response is purely on a trial and error basis, results being obtained subjectively from the user. The density of a packing determines the degree to which the response changes.

Fig. 3 depicts that the responses in F1` and F2 can be altered without appreciably affecting F3.

Fig. 3 illustrates the effectiveness of excessive damping when lamb's wool is used.

(ii) Sintered filters:

As reported by Decker (1974)*; Langford (1985) an alternate method of controlling the spectrum by mechanical means is to use sintered filters in the tubing. These are small cylinders of stainless steel ball sintered (welded) together in such a manner that predicts the degrees of acoustic attenuation that can result. They are used to reduce the lower portions of speech spectrum (F_1 and F_2) with minimal effects or highs (F_3). These are considered to have a repeatability of ±1dB for the same basic frequency response.

Georgeand Barr Hamilton (19780O) also reported for earmolds provided with high gain aids, the blocked senser can be removed without altering the output and occurrence of acoustic feedback using sintered venting.

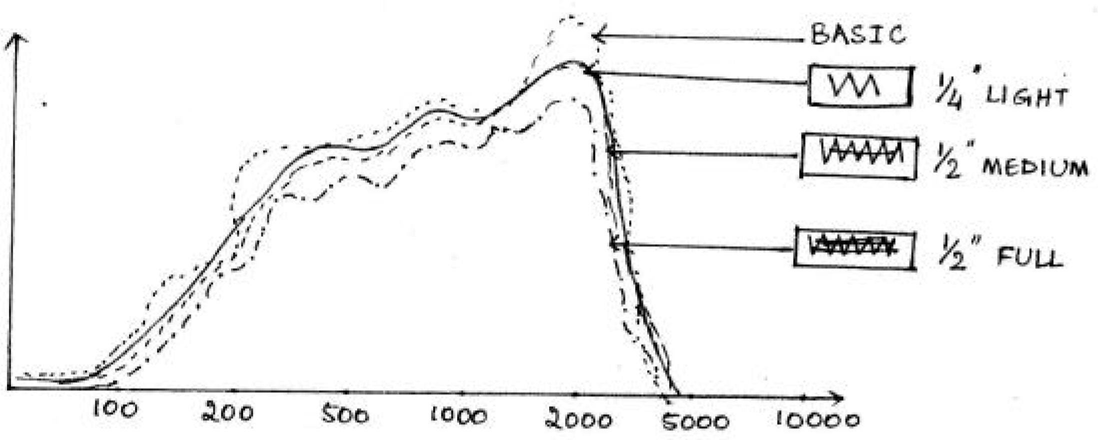


Fig.3: Lamb's wool - responses in F_1 and F_2 altered without affecting F_3.

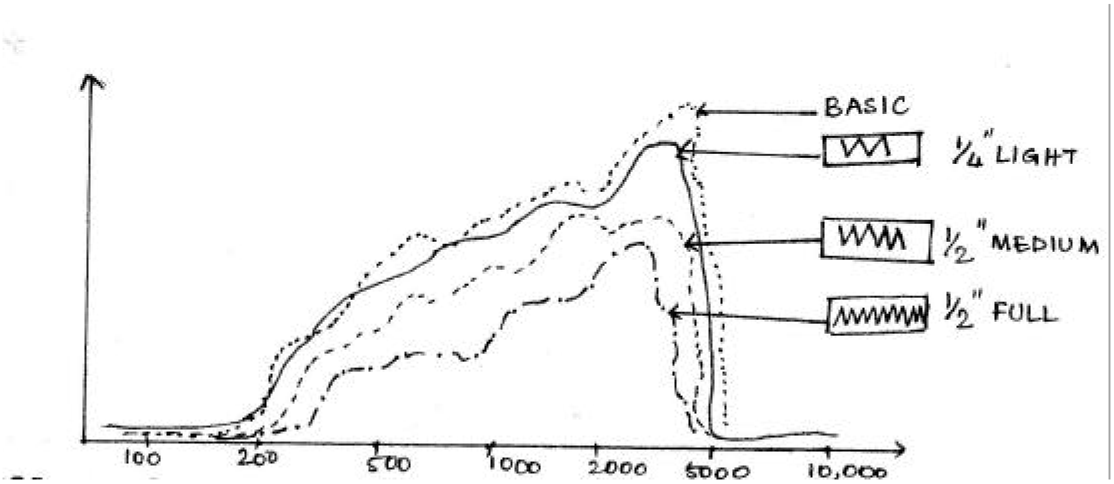


Fig.4: Effect of excessive damping with Lamb's swool.

Damping materials as conceived in this study may be classified as following:

(i) imported damping materials
(ii) indigenously available materials as damping materials.

In India, the widely used imported damping materials are Lamb's wool and sintered filters.

Apart from these, are discs with a small hole(s), fine metal screens and porons stainless stell plugs (Knowles BF series) has produced dampers which is made from very fine fused plastic mesh mounted in a small metal ferrule (ring) which fits into standard No. 13 tubing.

The materials used as dampers in the present study were as following:

a) Paraffin wax (b) Thermocol (c) Sponge (d) Bead of a large size (e) Bead of a small size (f) Cotton and (g) Lamb's wool.

METHODOLOGY

Selection of hearing aids:

Ten hearing aids were taken up for the study. All the 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 All India Institute of Speech and Hearing Clinic.

The hearing aids selected were both from companies of Indian and foreign hearing aid manufacturers.

Selection of dampers:

The damping materials that were chosen are as follows:

1) Paraffin wax
2) Thermocol
3) Sponge
4) Bead (big)
5) Bead (small)
6) Cotton
7) Lamb's wool.

Care was taken to see that these dampers were of the same size except bead (small). The size confirmed to that a sintered filter which had specific dimensions according to ANSI Standards.

Test Environment:

Test was carried-out in an air –conditioned sound treated room. The ambient noise levels inside the room were within permissible limits.

Instrumentation:

1. Fonix 6500 hearing aid test system
2. ½" test microphone
3. 2 cc couplers (HA1, HA2).

Connections:

Instruments were connected as shown in Appendix-A. Inside the hearing aid test box (Fonix 6500) connections were made as follows:

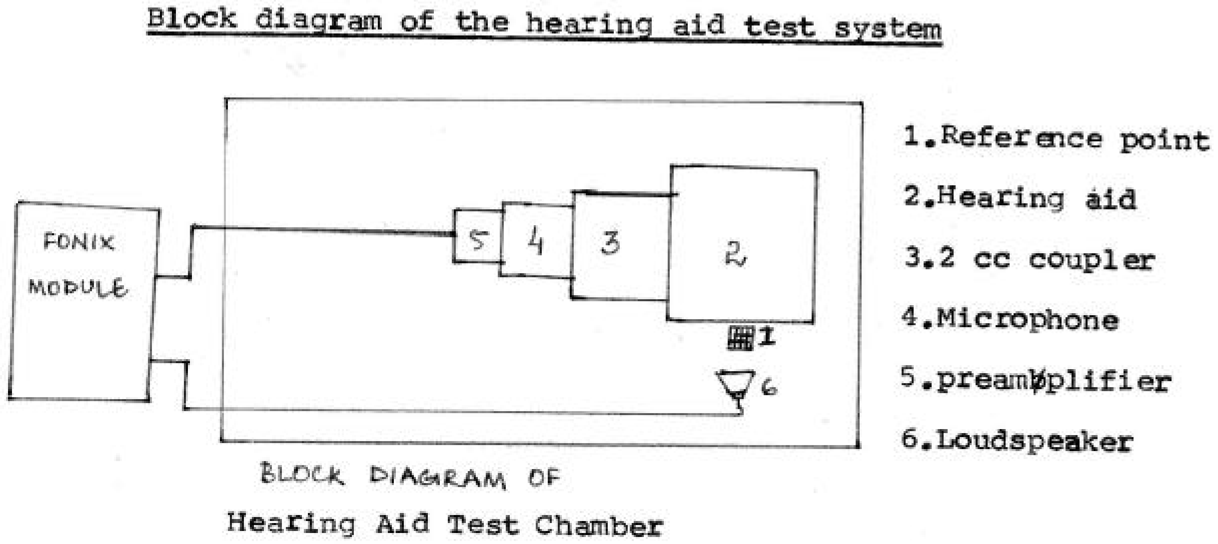
1. The test microphone was kept directly on the left side of the reference point (as for leveling).
2. The test microphone was connected to the 2 cc coupler (HA2) which was connected to the hearing aid by means of an adaptor. The hearing aid by means of an adaptor. The hearing aid was given power supply of 1.5 V from an inbuilt power supply my means of battery substitution pills (as for measurement of the electroacoustic characteristics of the hearing aid).

3. The test microphone was connected to the 2cc coupler (HA2) to which the earmold was coupled. To the tip of the tubing of the earmold the earhook of the behind-the-ear hearing aid was attached (as for the measurement of the electroacoustic characteristic of the hearing aid attached to an earmold.)
4. The test microphone was connected to the 2 cc coupler (HAI) to which the earmold was attached. Different dampers were inserted into the tubing of the earmold. 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 earhook.

The following conditions were maintained as constant in this study:

1. The length of the earmold tubing
2. The depth of insertion of the earhook into the tubing of the earmold.
3. The placement of the microphone of the hearing aid within the hearing aid test chamber.
4. The voltage to the hearing aid was kept constant by the user of inbuilt power supply within the hearing aid test chambers.
5. The voltage to the Fonix was kept constant by the use of a voltage stabilizer.

Block diagram of the hearing aid test system



Procedure:

a) Calibration:

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

b) Levelling:

The sound chamber lid was opened up and instrument was kept on for around 30 minutes for allowing in the instrument to warm-up. Levelling was done every time the instrument was switched on. By placing the microphone on the reference point and by pressing the level button the sound chamber was calibrated. The electroacoustic characteristic (EAC) of the ten hearing aids were measured under three conditions.

Condition-I:

The EAC 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 an inbuilt power supply through battery substitution pills. The volume control 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 pressing the IS button. The screen displayed the values of the following EACs = Max. OSPL 90, HFA SSPL 90 and HFA FOG.

Then the volume control was adjusted to match the gain displayed on the screen. Thus, the RTG was measured. Then, by pressing the continue button, the values of FL, F1, F2, harmonic distortion at 500Hz, harmonic distortion at 1 KHz and harmonic distortion at 1.6 KHz were obtained.

Condition-II:

The measurements were done in the same way as in the above condition except that the connection in the hearing aid test box was different. Here, the hearing aid was connected to the earmold which was connected to 2 cc coupler (HA1) by means of clay (Funtak). The microphone was connected to the 2 cc coupler (HA1).

Condition-III:

The same measurements were have in this condition too, but the dampers were inserted into the tubing of the earmold in addition to the connections in the condition-II. This was done for seven different conditions using seven dampers for all the ten behind-the-ear hearing aids.

The definitions of the 14 EACs measured thus in this study are given in Appendix-II.

RESULTS AND DISCUSSION

The purpose of the study was to determine the effect and compare the relative efficacy of different types of indigenously available materials used as dampers, on the electroacoustic characteristics of BTE hearing aids. As has been already mentioned in the preceding chapter, 14 EACs were measured for nine conditions one measurement of the hearing alone, one codition in which the hearing aid coupled to an earmold but without dampers and seven other conditions with the dampers inserted into the earmold.

The data was tabulated for each electroacoustic characteristics for ten hearing aid and nine conditions.

On subjecting these 14 electroacoustic characteristics to ANOVA it was found that four characteristics were significant at 0.01 level while the rest were not.

Table-1 indicates the parameters which were significant and those which were not so as determined by ANOVA.

Electroacoustic characteristics that are significant	Electroacoustic characteristics that are not significant
1. OSPL 90 HFA	5. OSPL 90 MAX
2. HFA FOG	6. FL
3. RTG	7. HD at 1KHz
4. HD AT 1.6 KHz	8. HD at 500 HZ
	9. DF at 1.6 KHz
	10. F1
	11. F2
	12. EIN
	13. CD1
	14. UG

Table-1: Showing the parameters which were significant as determined by ANOVA.

The relative efficacy between each condition was determined by using the mean and t-test scores. The findings are depicted in the Table-2.

Max.SSPL-90: It was found that the damping material paraffin wax was the most effective when compared to the rest of the damping materials. The damping material cotton was found to be next in the order of effectiveness.

However, the effectiveness of the damping materials sponge, thermocol, bead (small), bead (large) and lamb's wool were found to be the same as no significant difference was found between them in t-test.

HFA FOG: When effectiveness was determined the electroacoustic characteristics, HFA FOG, it was found that the order of effectiveness was the same as that obtained for OSPL 90 max. Paraffin wax was found to be the most effective damping material and thermocol, sponge, bead (1 large) bead (small) and lamb's wool was found to be less effective.

The electroacoustic characteristics, reference test gain (RTG) and harmonic distortion (HD) at 1.6 KHz were found to be non-significant from t-test scores. Hence, one may conclude that RTG and HD at 1.6 KHz are independent of the materials used for acoustic damping. Further, it may be speculated that HD at 1.6 KHz is dependent on the electronic circuitry and not on acoustic damping effects.

Rating	OSPL HFA1	HFA FOG	RTG	HD at 1.6 KHz
I	Paraffin wax	Paraffin wax	Sponge, theremocol, bead (small), bead (big) lamb'swool	Sponge, theremocol, bead (small), bead (big) lamb's wool.
II	Cotton	Cotton		
III	Sponge, theremocol, bead (small) bead (big) lamb'swool	Sponge, theremocol, bead (small) bead (big) lamb'swool		

Table- 2: Showing the effectiveness of dampers as obtained from t-test.

It is one of the principles of aural rehabilitation that one should employ strategies necessary for modification of ear molds pertinent to hearing aid fitting. It is in this regard, the present study aims to develop dampers that are efficient, cost-effective and easily available too.

From the results, it is evident that indigenously available materials such as paraffin wax, cotton etc. may be used in acoustic modification effectively. This may be of interest and concern to the hearing aid manufactures and dealers who can benefit from these dampers for their afore-mentioned qualities.

Further, from the point of view of the audiologists has been a demoralizing situation, as the fitting of a suitable hearing aid for a person with tolerance problem still remains spurious. This problem, has been alleviated to a certain extent by using AGCs, peak clipping etc. But, to one's chagrin, there's no permanent solution in these as there's distortion produced by the above circuits and an adverse signal-to-noise ratio.

Fortunately, a better solution can be afforded by these dampers. They not only prevent distortion and thereby an adverse signal-to-noise ratio but also help the hearing aid user to set the MPO of his hearing aid at a higher level.

Further, this damping effect prevents upward spread of masking thereby making speech clearer. This is an important implication of the study and has found to be in agreement with the study done by Chasin (1983).

As is thus evident, Paraffin wax may be singled out as the best damper to be followed next by cotton. Sponge, thermocol, bead (big), bead (small) and lamb's wool have been found to have negligible effects.

SUMMARY AND CONCLUSION

The aim of the present study is to determine the effects of indigenously made dampers on the electroacoustic characteristics of the behind-the-ear hearing aids.

The electroacoustic characteristics are measured for ten behind-the-ear hearing aids for nine different conditions. These comprised of the following:

1. Ist condition where the electroacoustic characteristics measurements were made for the hearing aid only.
2. 2nd condition where the electroacoustics characteristics measurements were made for the hearing aid with the earmold attached to it.
3. The next condition where the electroactoustic characteristics measurements were made for the hearing aid which was attached to earmolds with dampers inserted in them. In this condition, there were seven dampers and therefore, seven different measurements were made.

As in conceivable of this study, there is a significant difference between the different dampers measured for the electroacoustic characteristics OSPL 90, HFA FOG, RTG, HD at 1 KHz.

Paraffin wax has been found to possess the highest effect on damping. Cotton follows next and the other five damping materials namely, thermocol, sponge, bead (big), bead (small), lamb's wool have been found to have negligible effect.

It may be highlighted that this has immense practical significance with respect to acoustic modification where the hearing aid manufacturers may utilize these cost-effective, easily available materials as dampers, which are also efficient.

Suggestions for further study:

1. A study could be carried-out using these dampers using subjects by making use of insertion gain optimizer (IGO) hearing aid trail system.
2. Studies could be carried-out with these dampers inserted into the tubing of the earmold, at different positions of the earmold tubing; or placed within the earhook of the behind-the-ear hearing aid.
3. A study may be carried-out as part of an import substitution measure where the efficacy of these materials as dampers can be tested vis-à-vis imported dampers.
4. The frequency response curves of these dampers could be tested and the effects of these dampers on mid-frequencies could be studied, as dampers are known to enhance middle frequencies (Chasin, 1983).

APPENDIX- A

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

Photograph 2. Setup of instruments

APPENDIX –B

Saturation SPL (OSPL 90): It is important to know a 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 2-cc earphone coupler when the input SPL is 90 dB 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 the 1000, 1600 and 2500Hz SSPL 90 values.

High Frequency average full-on-gain (HFA-FOG) - is defined as the average of the 1000, 1600 and 2500 Hz SPL 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 60 dB, by adjusting the gain control so that the average of the 1000, 1600 and 2500Hz gain values are equal to the HF-average SSPL-90 minus 15± 1 dB.

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 aid.

Frequency range – The frequency range of an aid refers to the useful range of the frequency response. It is expressed by two numbers, one representing the low-frequency limit of amplification (f1) and the other high frequency limit (f2) with both numbers expressed in Hz.

Total harmonic distortion – Harmonic distortion is a result, primarily, of over loading the hearing aid amplifier or earphone. It occurs when the instantaneous output sound pressure of the hearing aid earphone is not directly proportional to the instantaneous sound pressure at the microphone. Measured at 500 Hz, 1000Hz, 1600 Hz.

DF. Distortion at 1 KHz (Intermediation 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 non-linearity.

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 1000 Hz input signal at a sound pressure level of 65 dB.

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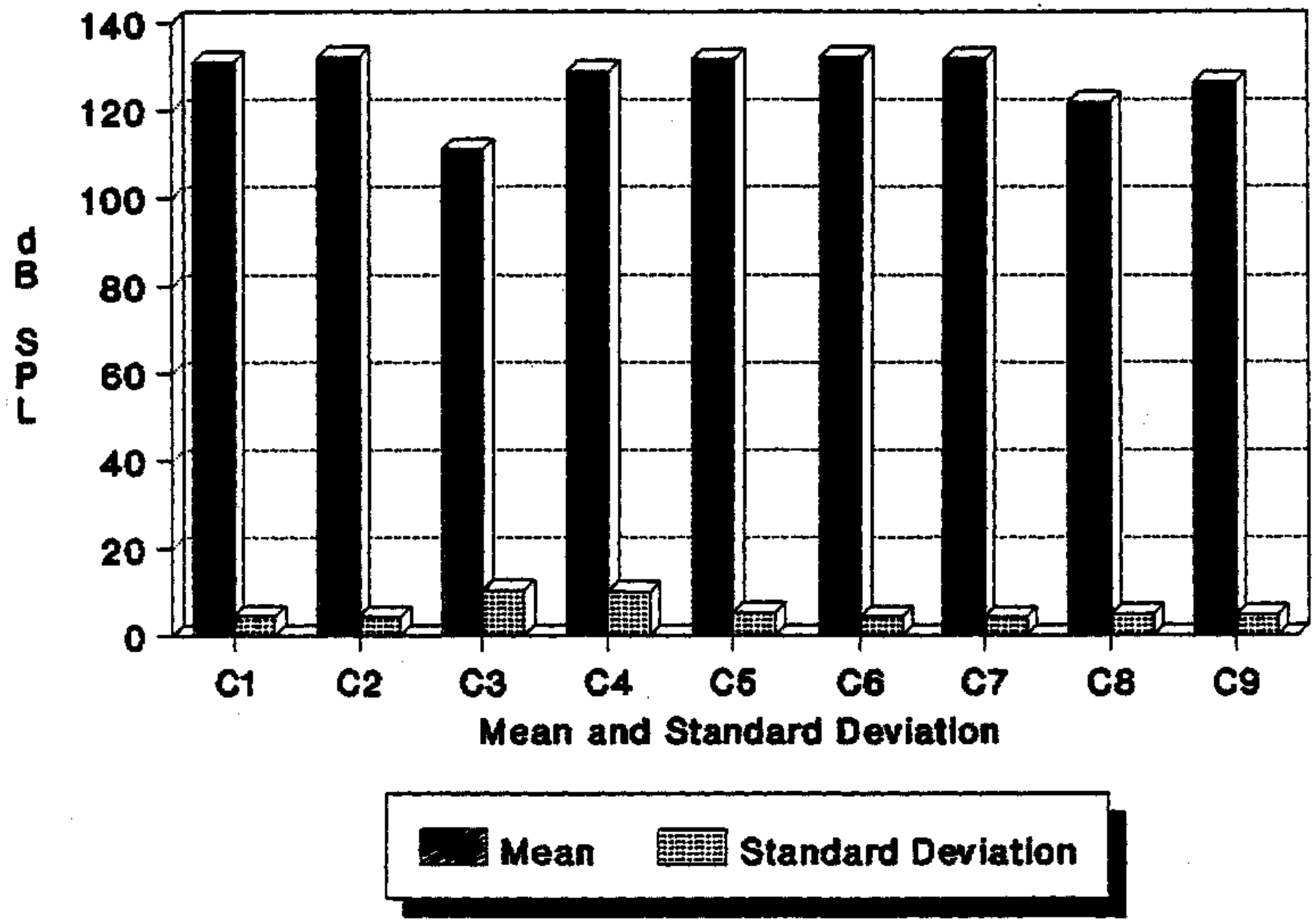
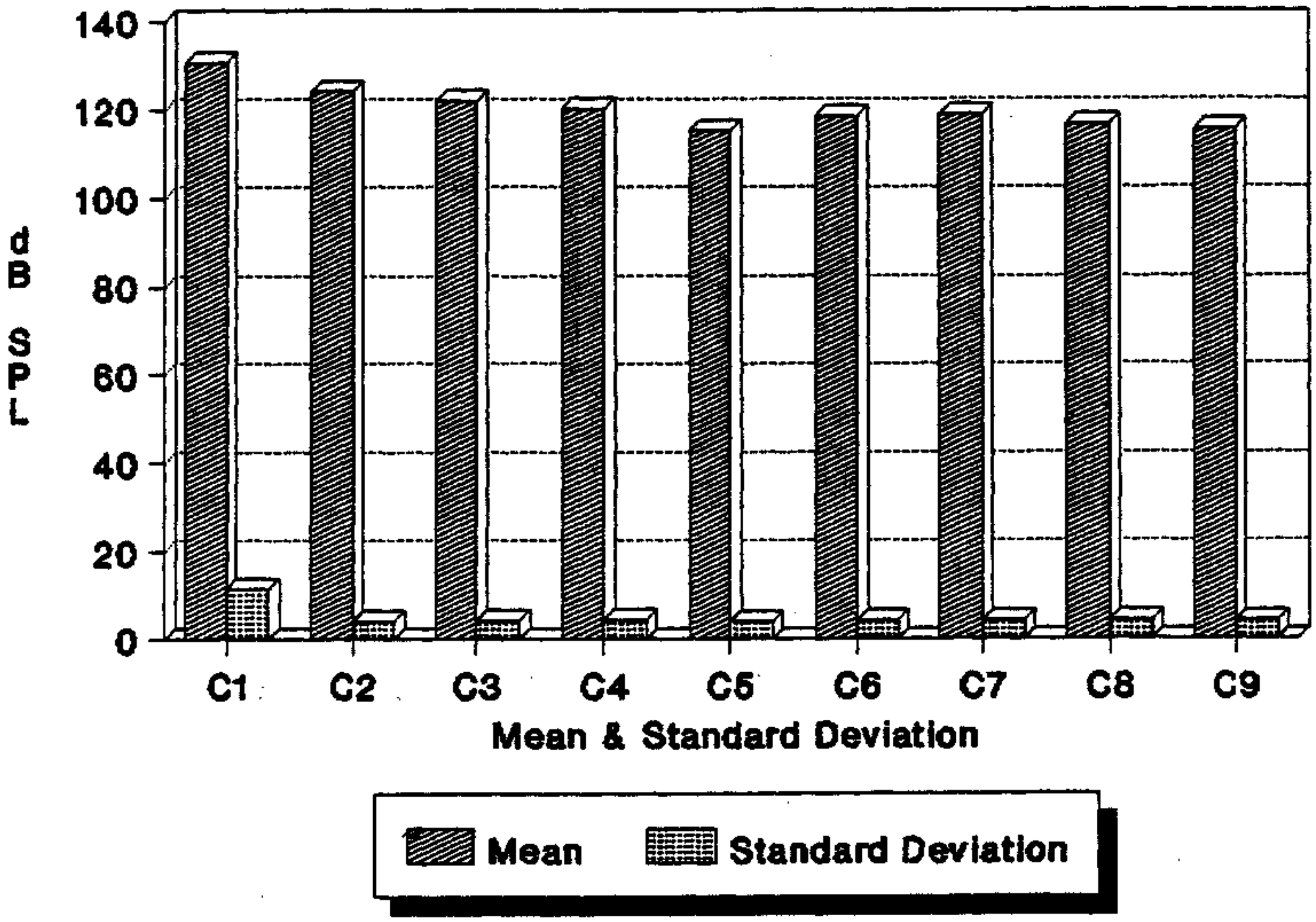


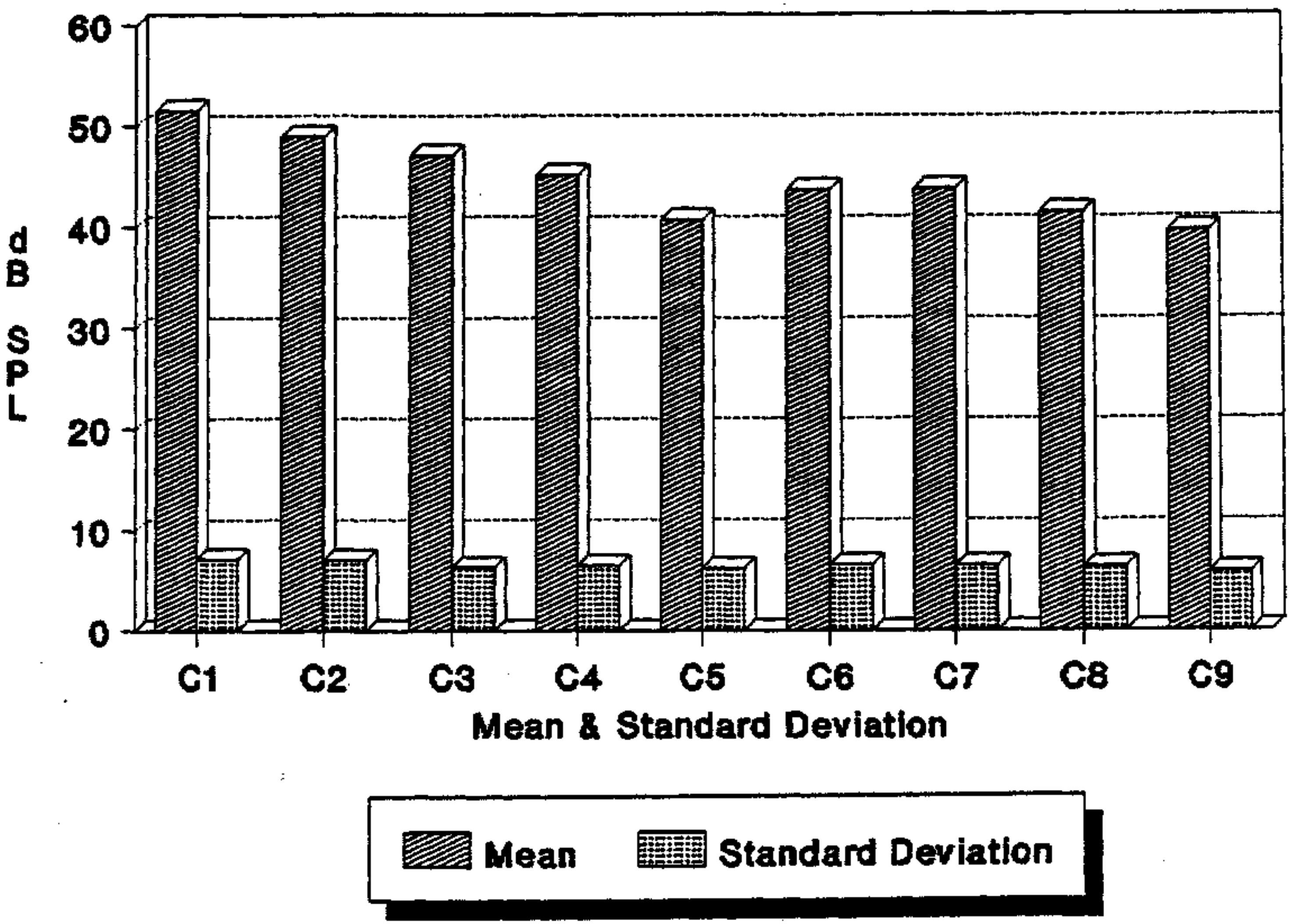
OSPL 90 (MAX)

dB SPL
140
120
100
80
60
40
20
0
C1
C2
C3
C4
C5
C6
C7
C8
C9
Mean and Standard Deviation
Mean
Standard Deviation

OSPL 90 (HFA)


140
120
100
80
60
40
20
0
dB SPL
C1
C2
C3
C4
C5
C6
C7
C8
C9
Mean & Standard Deviation
Mean
Standard Deviation

HFA FOG


60
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C5
C6
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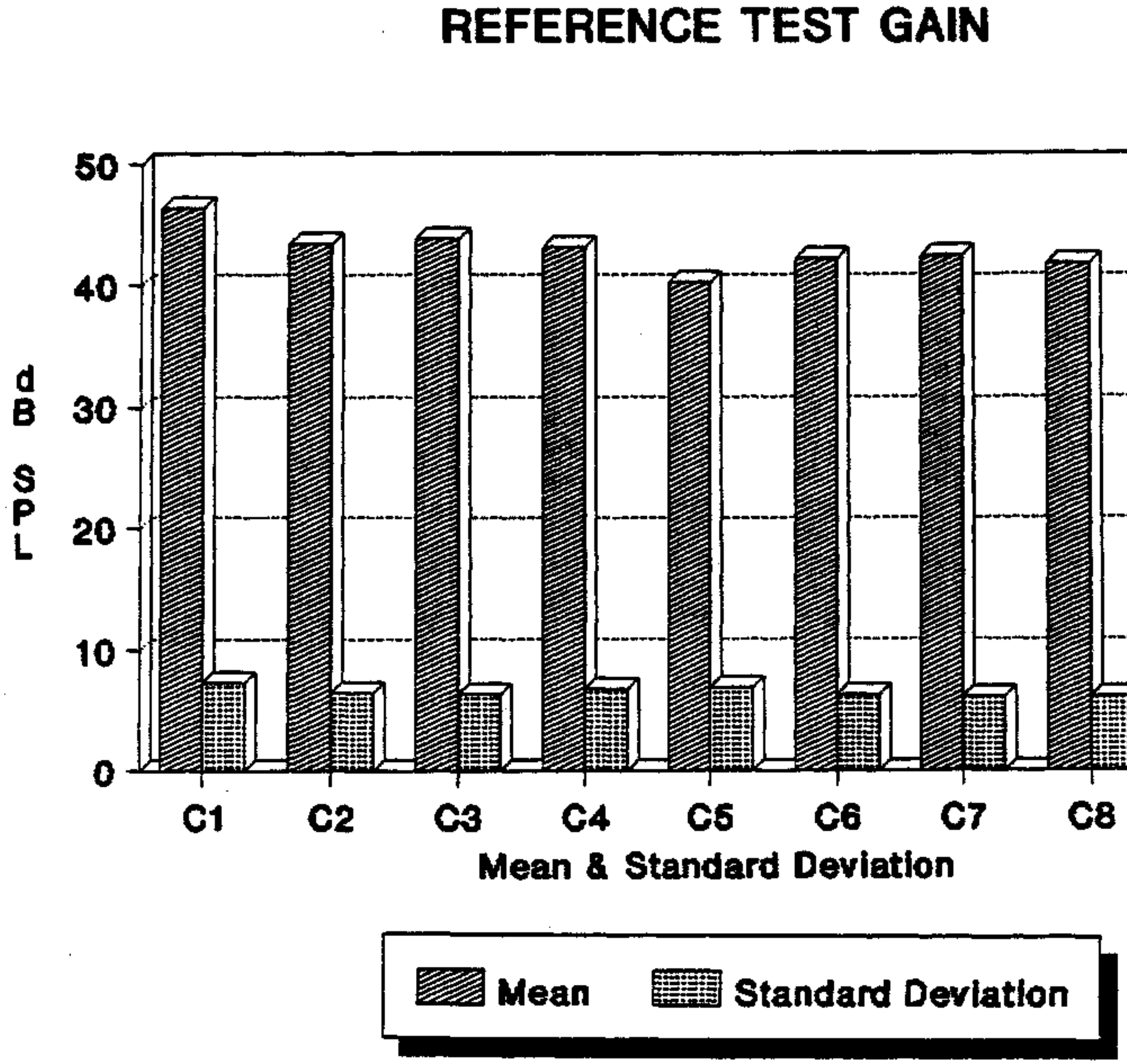
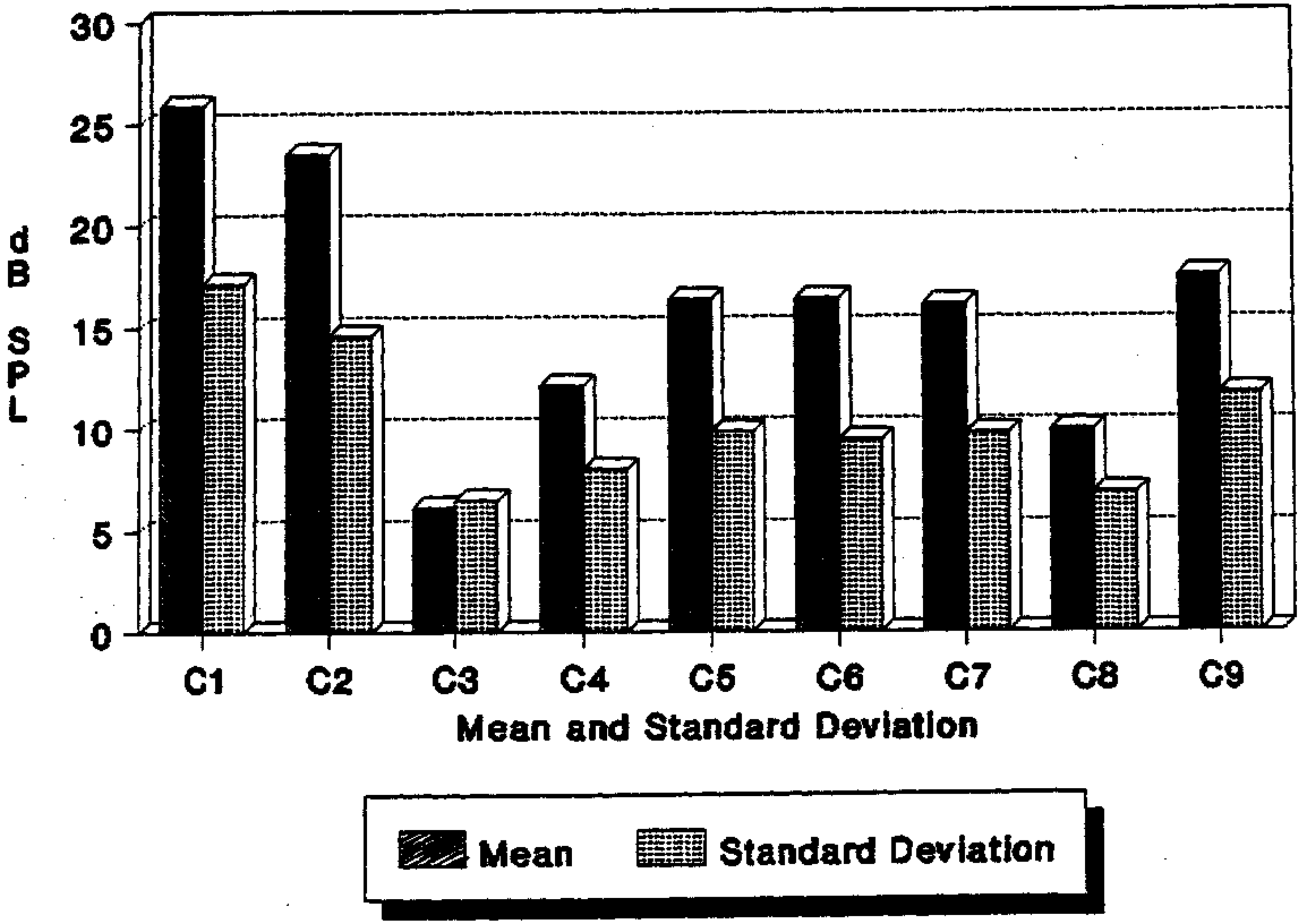
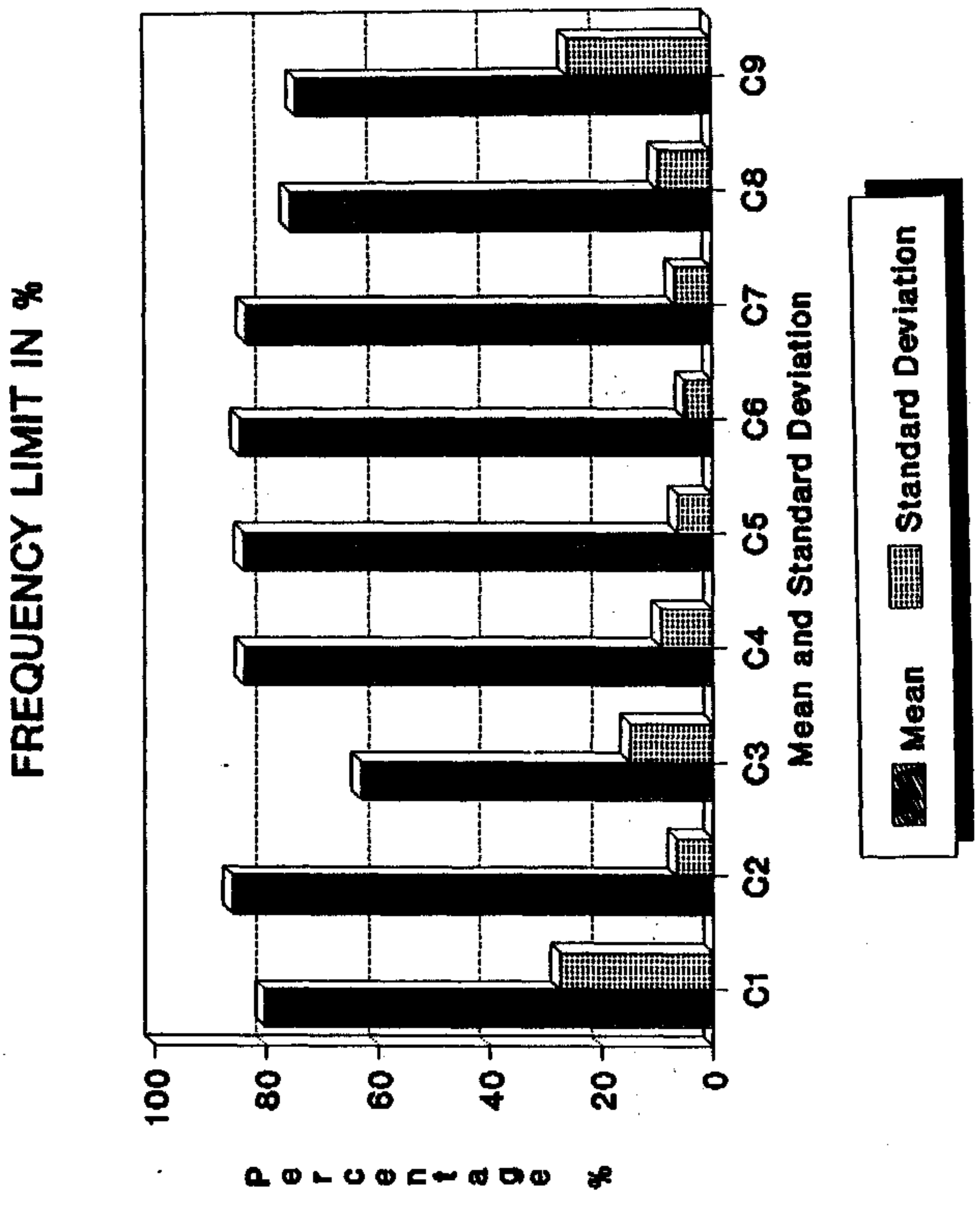
C8
C9
Mean & Standard Deviation
▨ Mean
▦ Standard Deviation


REFERENCE TEST GAIN
d
B
S
P
L
50
40
30
20
10
0
C1
C2
C3
C4
C5
C6
C7
C8
C9
Mean & Standard Deviation
Mean
Standard Deviation

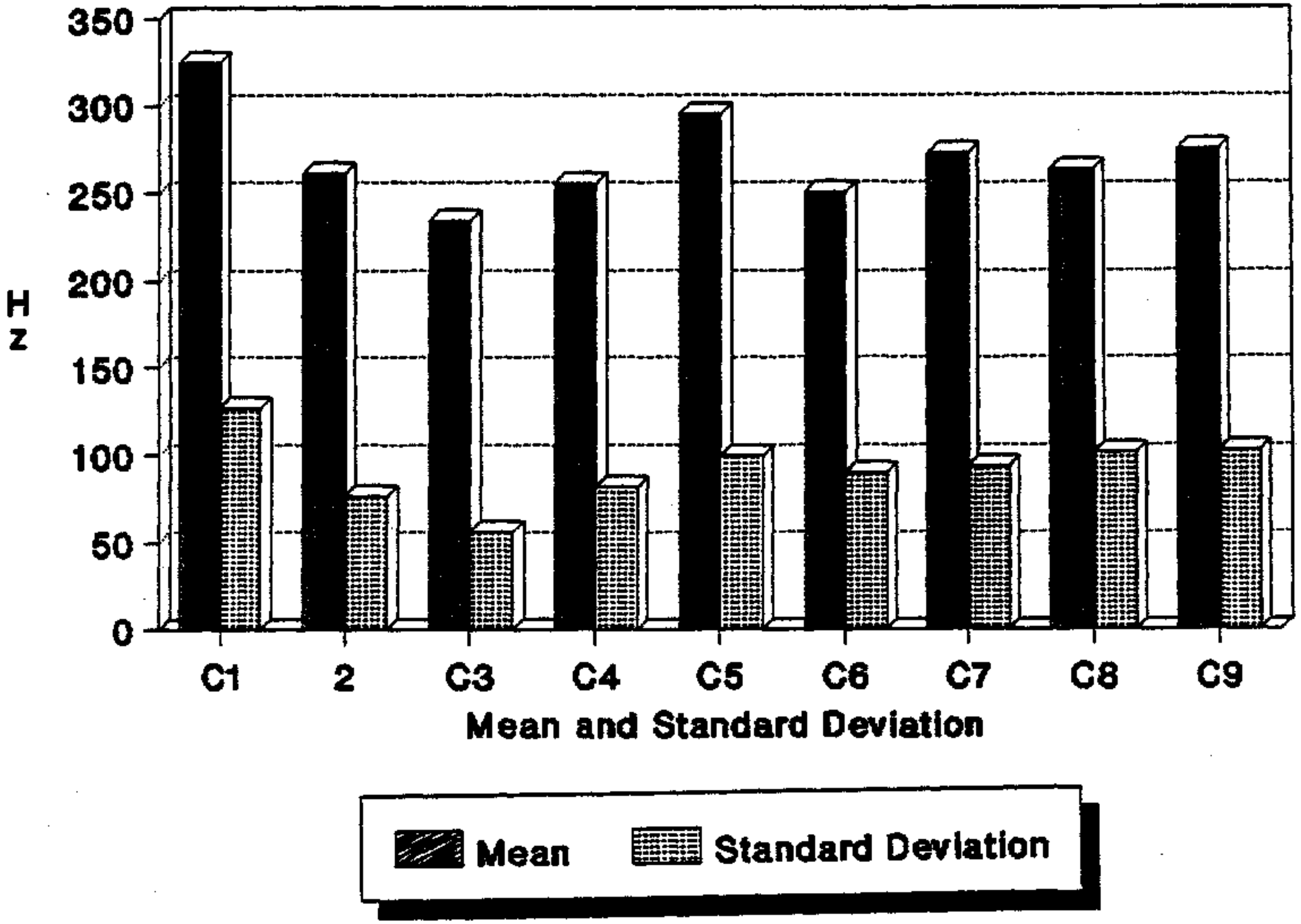
USE GAIN

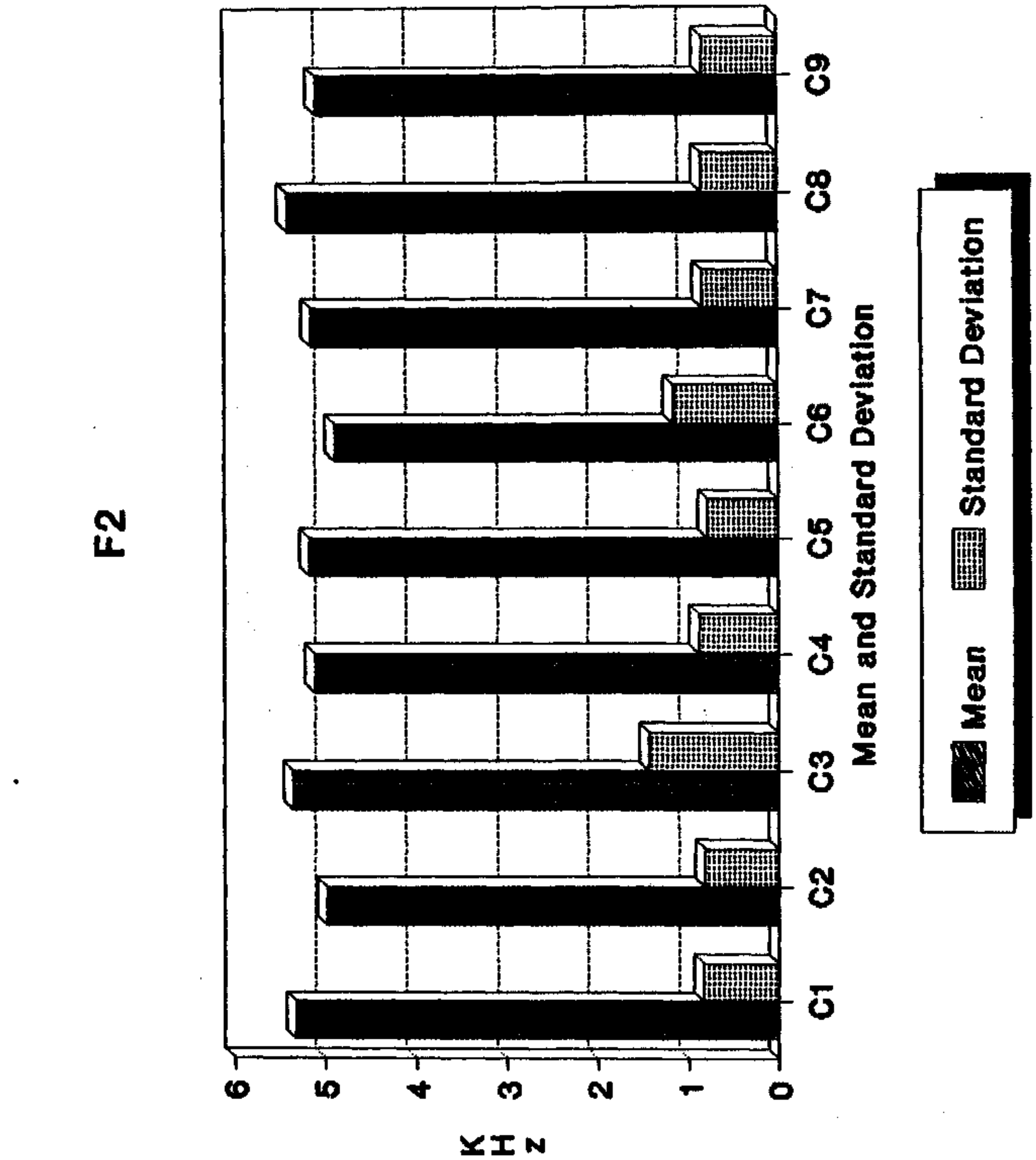

30
25
20
15
10
5
0
dB SPL
C1
C2
C3
C4
C5
C6
C7
C8
C9
Mean and Standard Deviation
▨ Mean
▦ Standard Deviation



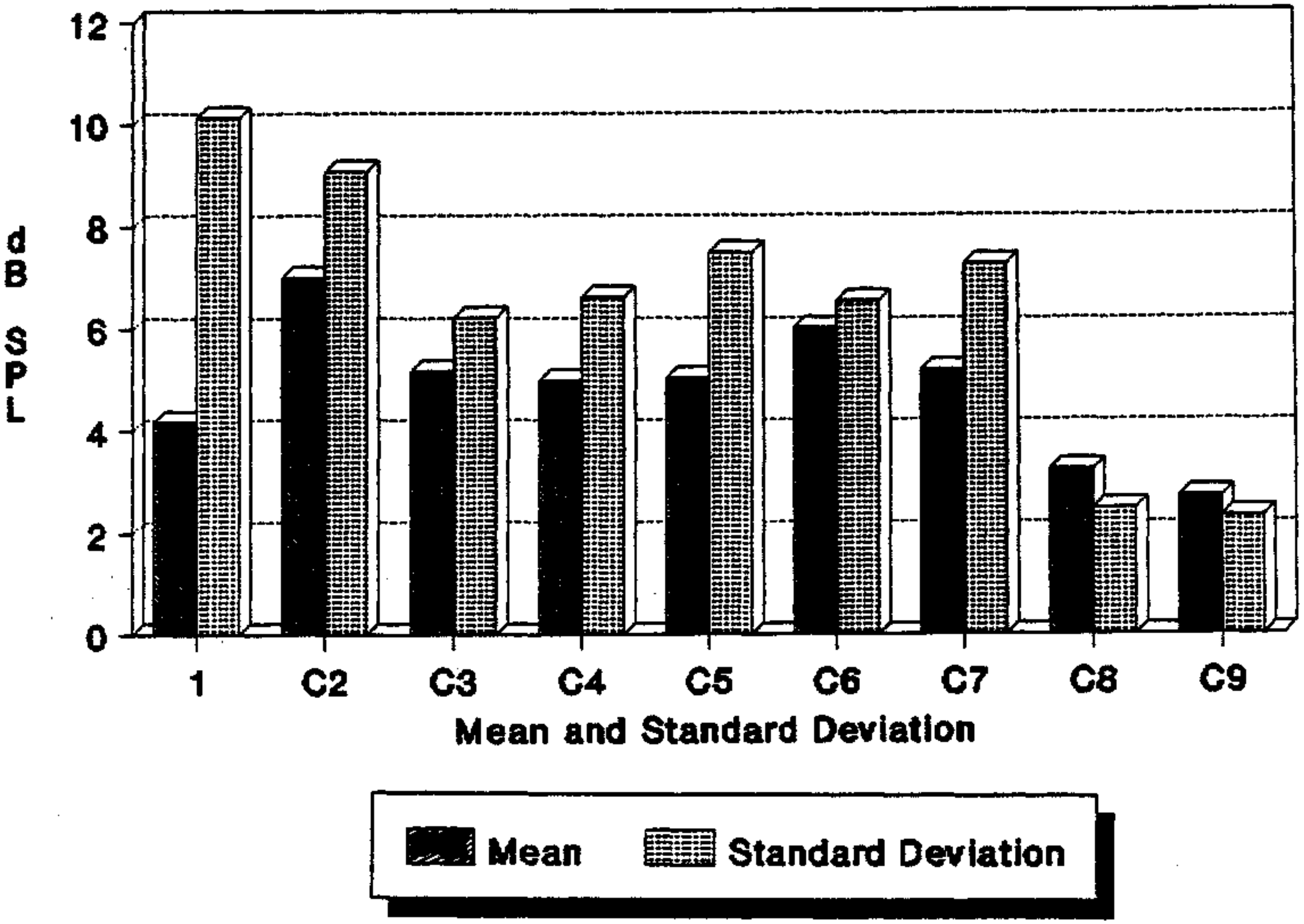
FREQUENCY LIMIT IN %

F1

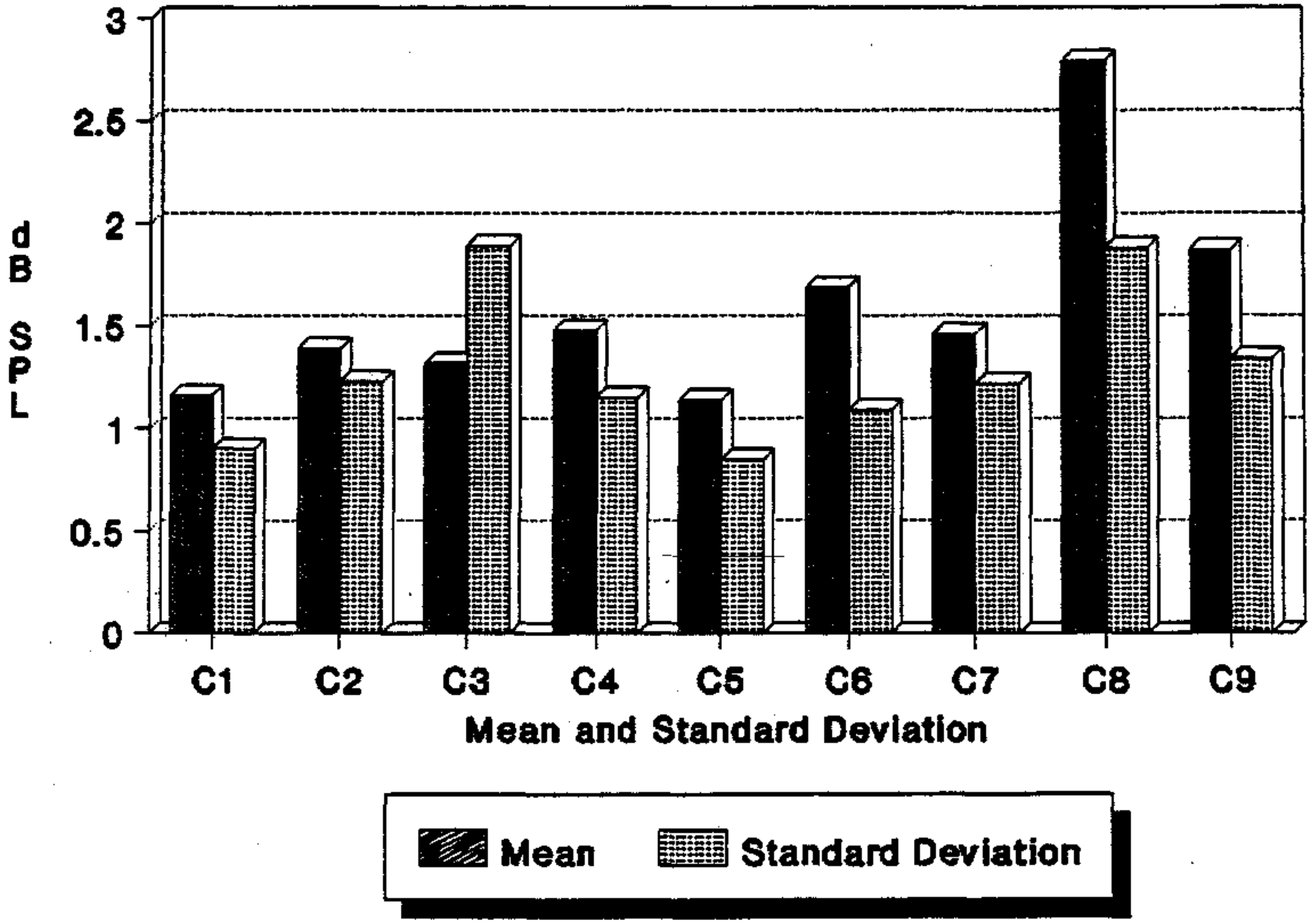

350
300
250
200
150
100
50
0
Hz
C1
2
C3
C4
C5
C6
C7
C8
C9
Mean and Standard Deviation
Mean
Standard Deviation

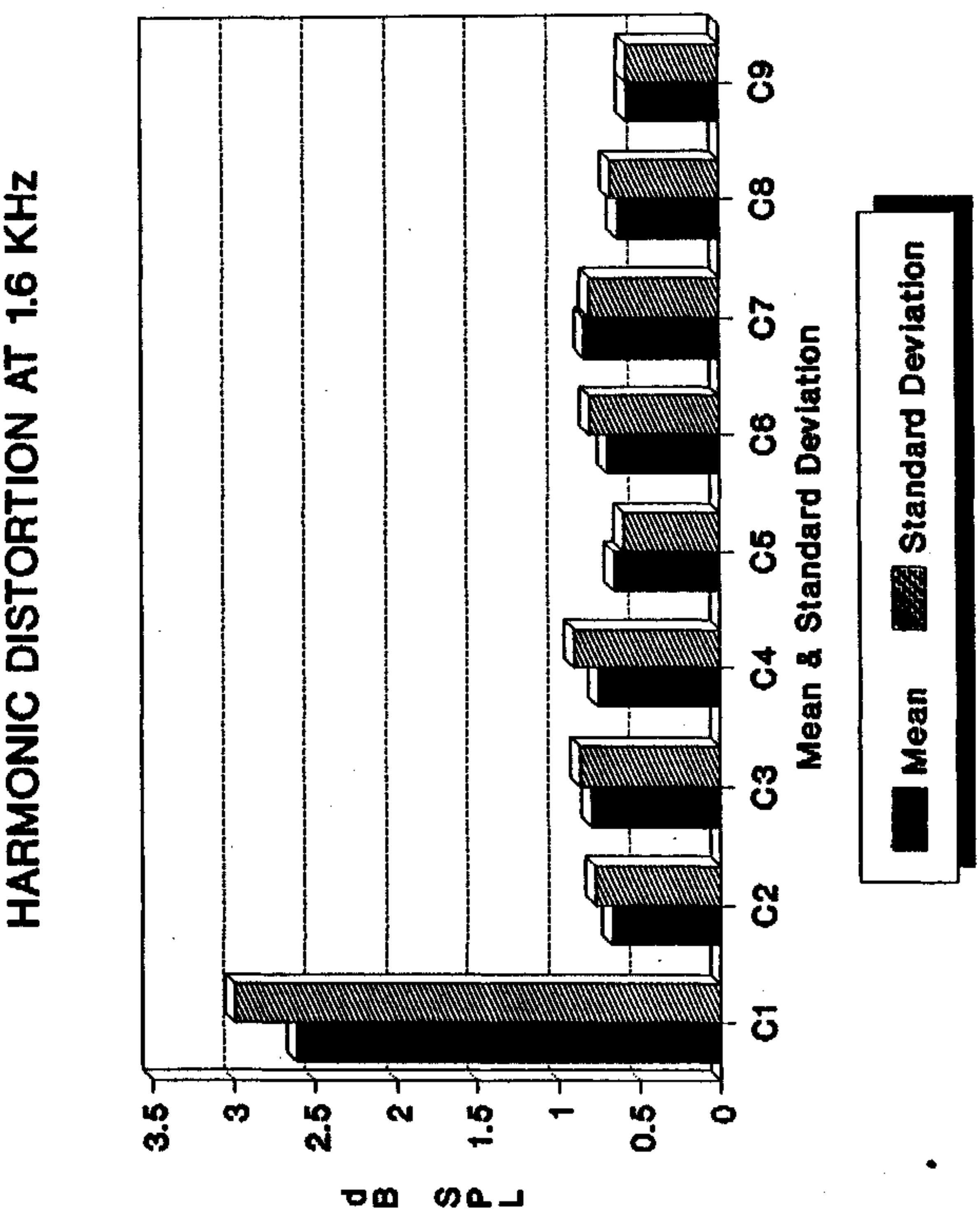

F2
KHz
0
1
2
3
4
5
6
C1
C2
C3
C4
C5
C6
C7
C8
C9
Mean and Standard Deviation
Mean
Standard Deviation

HARMONIC DISTORTION AT 500 Hz

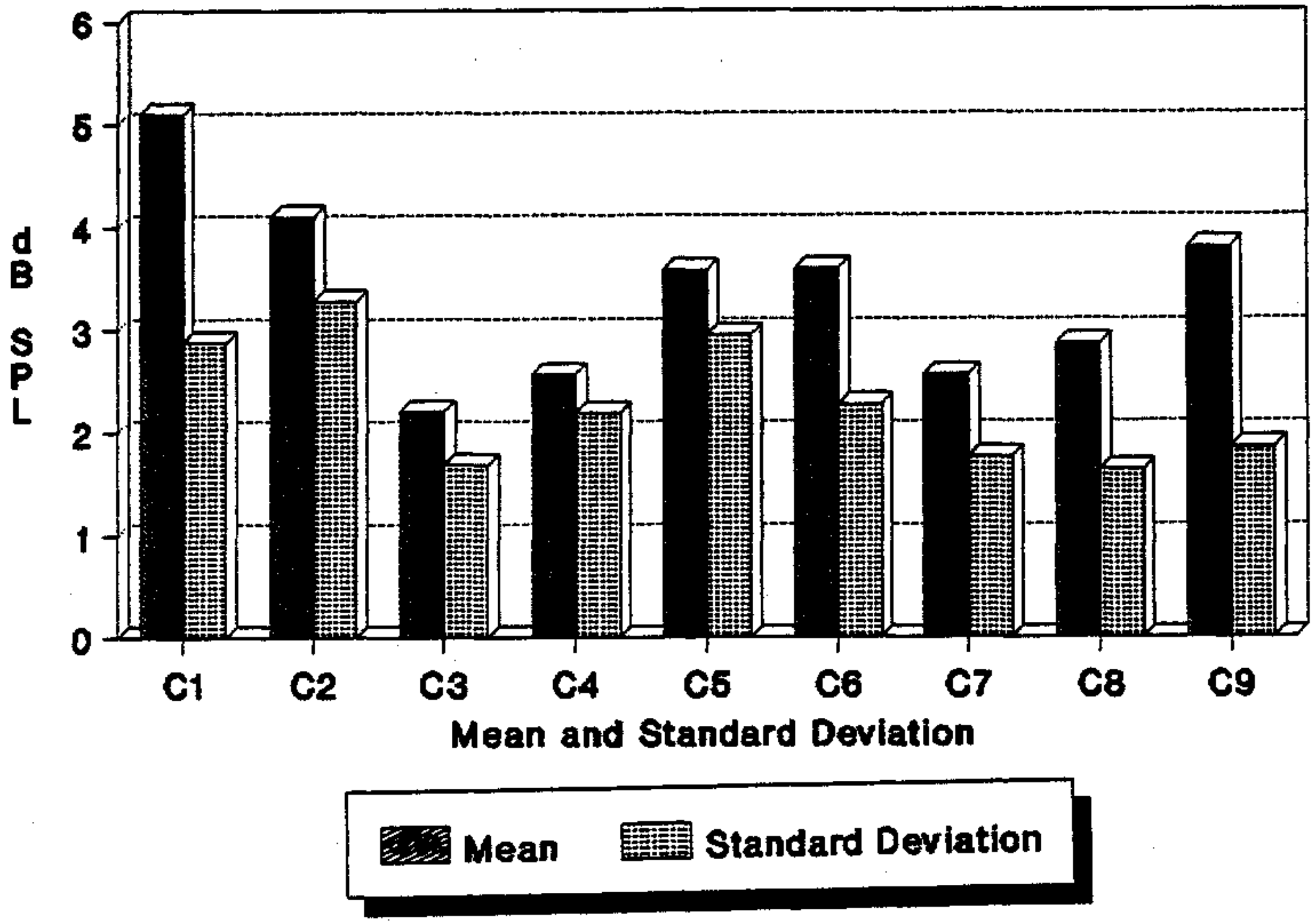


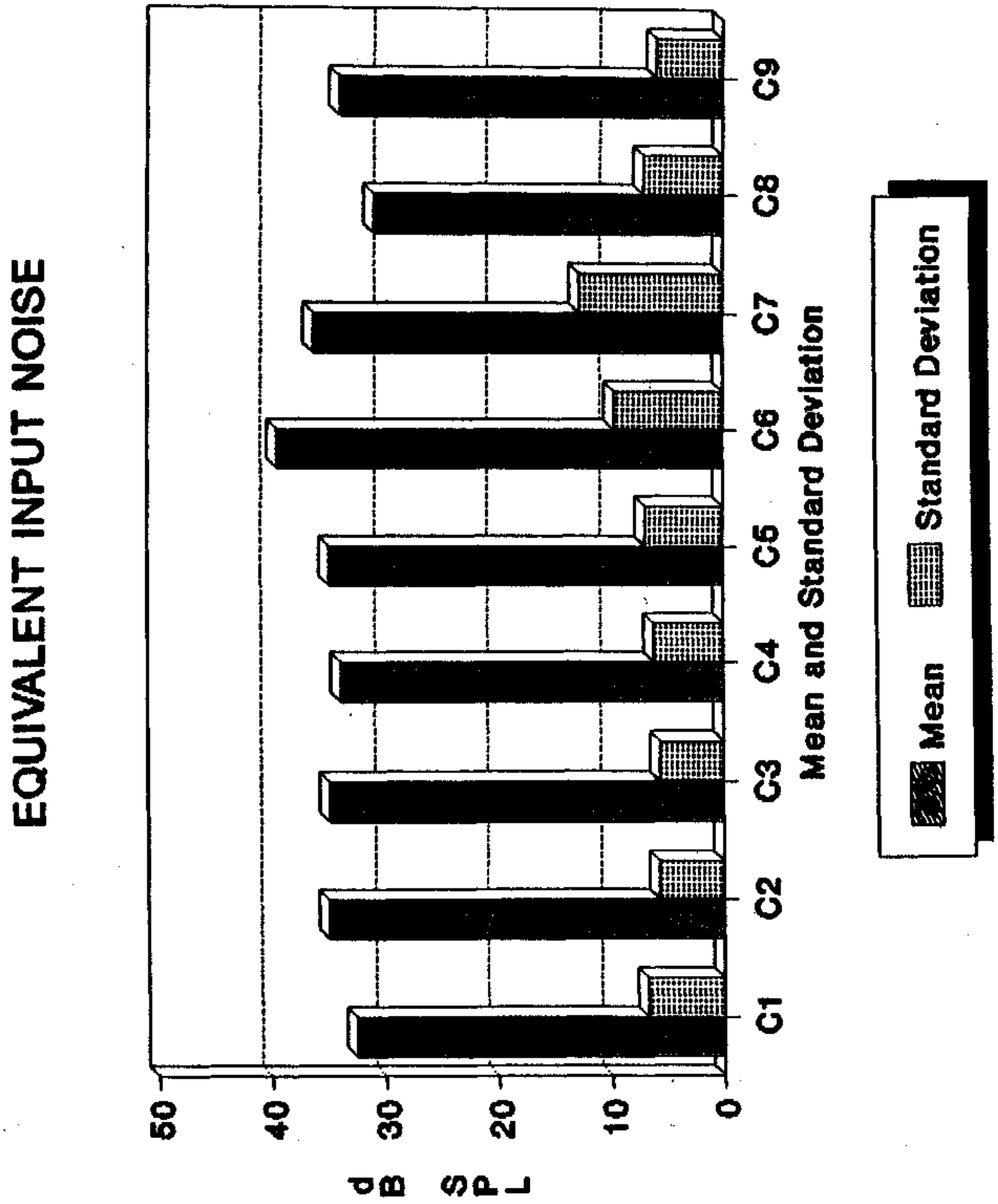
HARMONIC DISTORTION AT 1 KHz




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

D.F. DISTORTION AT 1 KHz





EQUIVALENT INPUT NOISE

CURRENT DRAIN