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ABSTRACT

This study concerns the diffraction of sound around flexible partitions used in teaching spaces. It includes a comprehensive study of the acoustical conditions in several school buildings in India, Malaysia, Singapore, and Sri Lanka. The noise reduction properties of some typical partitions the minimum height of the partition between two teaching spaces, the material of the partitions, and the position of chalk-boards were some of the important factors considered in the study. Noise levels prevailing in the classrooms of different countries were also measured. (Author/MLF)

SOUND DIFFRACTION AROUND MOVABLE PARTITIONS IN TEACHING SPACES

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Unesco Regional Office for Education in Asia
Darakarn Building, 920 Sukhumvit Road
P.O. Box 1425
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N.K.D. Choudhury

EDUCATIONAL BUILDING REPORT 1

UNESCO REGIONAL OFFICE FOR EDUCATION IN ASIA, BANGKOK, 1973

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SUMMARY

This study was undertaken by the Central Building Research Institute (C.B.R.I.), Roorkee, India, in fulfilment of a contract with the Unesco-sponsored, Asian Regional Institute for School Building Research. It concerns the diffraction of sound around flexible partitions used in teaching spaces and includes a comprehensive study of the acoustical conditions in several school buildings of India, Malaysia, Singapore and Sri Lanka, as well as measurement of noise reductions of some typical flexible partitions. The current trend is to use these partitions for dividing teaching spaces (1). Consequently the minimum height of the partition between two teaching spaces, the material of the partition, position of chalk-board etc., were some of the important factors which are considered in the study. Noise levels prevailing in the class-rooms of different countries were also measured, as these primarily decide the acoustical conditions.

The value of the speech articulation index $\triangle_1$ and the intruding speech articulation $\triangle_2$ were measured in every school. In addition, subjective tests were also conducted to find out percentage error committed by the subjects. Correlation curves were then drawn between $\triangle_1$ and $\triangle_2$ showing percentage error.

The set of points relating $\triangle_1$-E and $\triangle_2$-E were plotted each on a single figure. The points for each country fit mean curves having a correlation exceeding 80 per cent. From these curves were found the mean values of S/N and IS/N for 15 per cent error and for each country.

It is found that the three countries, India, Malaysia and Sri Lanka, require an S/N ratio of about 13 db. whereas for Singapore it is 10 db. The IS/N figures are 14 db. for Malaysia, Singapore and Sri Lanka, and 10 db for India. The study led to the following conclusions:

(1) No child should be more than 7 metres away from the teacher.

(2) Flexible partitions should have a noise reduction of at least 4 db.

(3) The partition height should be 2 metres when teachers are back to back and 2.4 metres when they are on opposite ends of adjoining class-rooms.

(4) Noise levels in class-rooms should not exceed 60 db.

RESUME

Cette étude, faite par le Central Building Research Institute de Roorkee (Inde) en exécution d'un contrat passé avec l'Institut régional asiatique de recherches sur les constructions scolaires (patronné par l'Unesco), porte sur la diffraction des ondes sonores contournant les cloisons mobiles que l'on utilise couramment pour délimiter les "espaces d'enseignement" dans les écoles. Elle a comporté une analyse acoustique poussée de plusieurs écoles de l'Inde, de la Malaisie, de Singapour et de Sri-Lanka, ainsi que la mesure de l'atténuation du bruit obtenue au moyen de divers types de cloisons mobiles. Parmi les paramètres importants pris en considération, on citera : la hauteur minimale que doit avoir une telle cloison entre deux espaces d'enseignement adjacents, les matériaux dont ces cloisons sont faites, l'emplacement du tableau à écrire, etc. On a aussi mesuré le niveau du bruit qui règne habituellement dans les écoles de différents pays, car ce paramètre est l'un des principaux qui déterminent la condition acoustique d'un local.

Dans chaque école, on a mesuré l'indice $\triangle_1$ de compréhension des paroles prononcées dans la salle même et l'indice $\triangle_2$ de compréhension des paroles venant de l'extérieur. On a procédé aussi à des tests subjectifs pour évaluer le pourcentage d'erreurs (E) commises par les élèves. Des courbes de corrélation entre $\triangle_1$ et $\triangle_2$ ont ensuite été tracées, montrant l'amplitude des erreurs.

Les valeurs de $\triangle_1$-E et de $\triangle_2$-E ont ensuite été rassemblées sur deux graphiques. Les points relatifs à chaque pays dessinent des courbes moyennes dont la corrélation est supérieure à 80%. De ces courbes on a déduit les valeurs moyennes des rapports "parole/bruit" et "parole intruse/bruit" pour un taux d'erreur de 15% pour chaque pays.

On a constaté que dans trois pays (Inde, Malaisie et Sri Lanka) le rapport "parole/bruit" doit être d'environ 13 db. alors qu'il est de 10 db. à Singapour. Les valeurs du rapport "parole intruse/bruit" sont 14 db. pour la Malaisie, Singapour et Sri Lanka, et 10 db. pour l'Inde. L'étude a abouti aux conclusions suivantes :

1. Aucun élève ne doit être à plus de 7 mètres de distance du maître.
2. Les cloisons mobiles doivent réduire de 5 db. au moins le bruit venant de l'espace d'enseignement adjacent.
3. Une cloison doit avoir 2 mètres de hauteur lorsque les deux maîtres, de part et d'autre, se tournent le dos, et 2,4 mètres lorsqu'ils se font face mais sont situés aux extrémités opposées des deux salles.
4. Le niveau de bruit dans les classes ne doit pas dépasser 60 db.

1. INTRODUCTION

Teaching spaces should be segregated, so as to reduce disturbance from one space to the other. One of the criteria which found general acceptance was that an acoustical separation of 40 db. is desirable between two classrooms.(1) The current trend in construction of school buildings is to design classrooms without interior partitions as this is considered as providing a better relationship between space and function. The achievement of a complete acoustical separation is impossible in such open type schools. The objective of this investigation is therefore to determine what minimum acoustical separation is necessary between such teaching spaces so that one group of students may work undisturbed by the adjoining groups.

It has been shown by many workers, especially by Watters in U.S.A., that the main source of disturbance in office and school buildings is intruding speech * sound and not always the continuous type of noise such as from air conditioners or exhaust fans. (2) The latter, when at a reasonably low level, provide a comforting background sound. It is well established that intruding speech sounds are objectionable when they become intelligible. It is not the loudness of the intruding noise which is important but the numerical differences in db. between the levels of intruding noise and "acceptable" noise. (2) Thus in a quiet school, an intruding speech level of only 50 db. (in the 600-1200, 1200-2400 and 2400-4800 cps. bands) may be rated as objectionable while in a moderately "noisy" school, the intruding speech levels may increase to about 60 db. before becoming objectionable.

The difference between speech levels and acceptable background noise levels is important for speech intelligibility. Speech sounds are composed of several octave band frequencies. Therefore, the difference between speech and background noise in each of the frequency bands has an important bearing. The relative importance of speech levels in various frequency bands varies from virtually, no importance for the 20-75 and 75-150 cps. bands, small importance for 150-300 cps. bands, maximum importance for 1200-2400 cps. bands and slightly less importance for 2400-4800 cps. bands. This is the role of importance function (IF) in speech sounds or intruding speech sounds.

The figure in parentheses refer to references given in the bibliography.

* Note that *undesirable* speech sounds are termed here as intruding speech or intruding noise.

These ideas form the basis of a design procedure for choosing sound isolating structures such as partitions between two teaching spaces. The procedure takes into account the following aspects of classrooms:

1. The speech effort (conversational speech, raised voice, loud voice etc).
2. The privacy requirements of the students.
3. The level of the background noise in the space.
4. The level of the intruding noise and hence the required noise reduction between the spaces.
5. The desired probabilities that the students will be able to carry on their studies without distraction.

The present investigation envisages assessment of the acoustical conditions in primary school buildings in four Asian countries, Sri Lanka, India, Malaysia and Singapore, with special reference to the function of sound reducing partitions. Such partitions when scientifically designed and used in appropriate locations, function efficiently to reduce unwanted noises.

2. SCOPE OF INVESTIGATION

Two basic schemes appear in the literature; [3] one is the "acceptable level" scheme which assumes that people's reactions to a sound are uniquely related to its level or loudness. While it may be true that the annoyance and sound pressure levels are related for certain continuous types of sounds such as those from air conditioning or traffic, we have come to believe that annoyance due to information carrying sound, such as speech, conversation, dictation etc., is determined primarily by the intelligibility and not by the level of these sounds. The first scheme is inadequate in the sense that it equates all sounds of the same level, regardless of their character. The other scheme is a "categorization" scheme which prescribes, for example, a 40 db. partition between all class rooms. Many rooms, however, do not require as much as 40 db. isolation. Some rooms may work with lesser insulation.

A rating scheme has been described by Watters et. al. for the speech privacy in office buildings. It is not known whether the scheme is applicable to other kinds of spaces. Furthermore, the study advocates some stringent requirements of partition walls which may not be applicable to interior partitions for open type schools. Investigation was, therefore, undertaken to measure the noise reduction of various types of interior partitions which are or may be usable in school buildings in Asian countries. Besides these objective measurements on partitions, acoustical conditions in teaching spaces were also evaluated subjectively by measuring the response of the children to their teacher giving a lesson.

3. DEFINITIONS OF TECHNICAL TERMS

(a) Articulation Index (A I), is an index of the ability to recognize speech components in the sound such as dictation given by the teacher. (AI) values higher than 0.3 are desirable.

(b) Intruding Articulation Index (I A I), is an index of the ability to recognize speech components from external intruding sources, such as a TV set or teacher/student in the adjoining room or space. IAI should be as low as possible so that the intruding sounds are not intelligible. Values of IAI less than 0.15 appear a desirable criterion.

(c) Speech to Noise ratio, expresses in decibels (db) the difference between the speech level and the background noise level. This is actually the ratio of pressure levels of the speech sound and the noise. It is this ratio, rather than the individual sound levels, on which the intelligibility depends. For schools in U.S.A. a speech to noise ratio of 12 db. minimum has been specified.

(d) Noise Reduction (NR), specifies the overall reduction of sound level from one classroom to another. This is the amount of "acoustical separation" between two classrooms, and arises from the obstruction of sound by the partition as also from room absorption.

(e) Any unwanted sound that may produce on the recipient, distraction, disturbance or annoyance is termed as "Noise" It may be classified in three categories:

   (i) Internal Noise: The internal noise is one which is generated inside the classroom, Fig 1. (a)

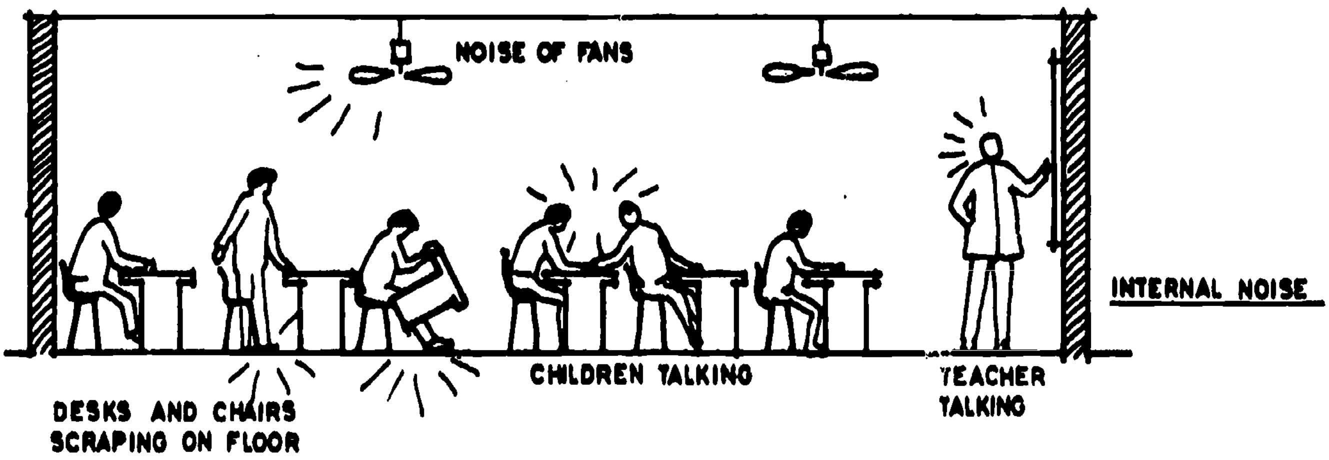

Figure 1 (a)

(ii) External Noise: External noise originates somewhere outside but finds its way into the classroom through doors, windows and other openings. Much of the external noises originates in the neighbouring streets and playgrounds, Fig 1. (b).

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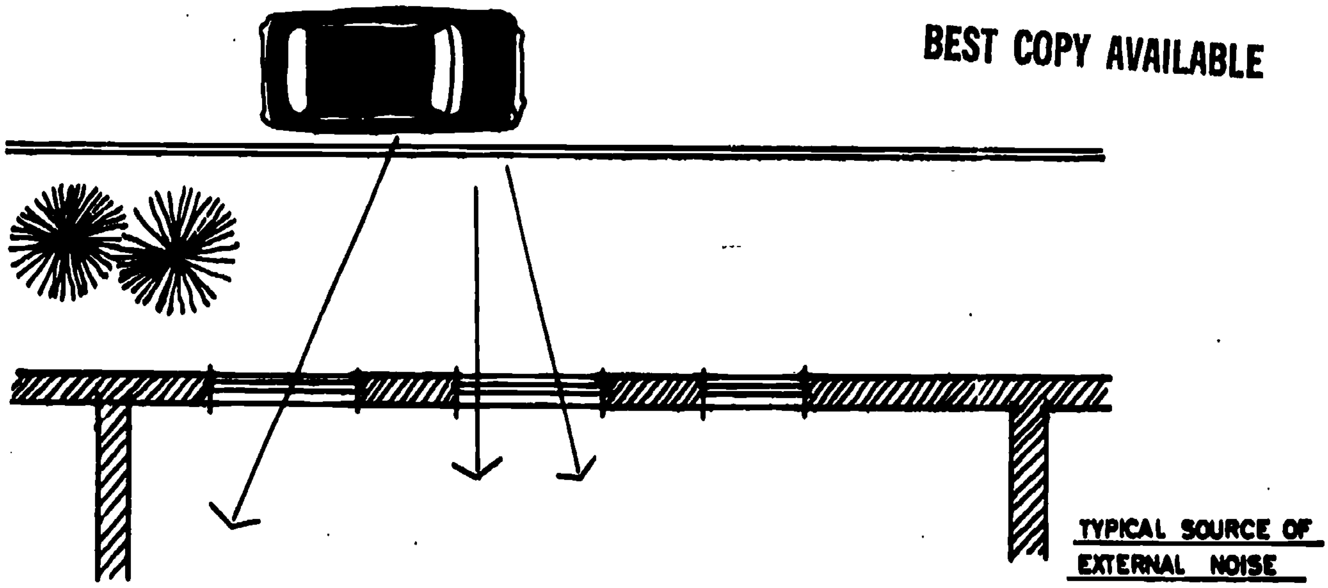


Figure 1 (b)

(iii) Intruding Noise: Intruding noise, as the name implies, originates in classrooms or teaching spaces and travels across common partitions into another classroom where teaching is in progress, Fig 1. (c). Such noises are common in teaching spaces separated by buffer spaces or by flexible partitions.

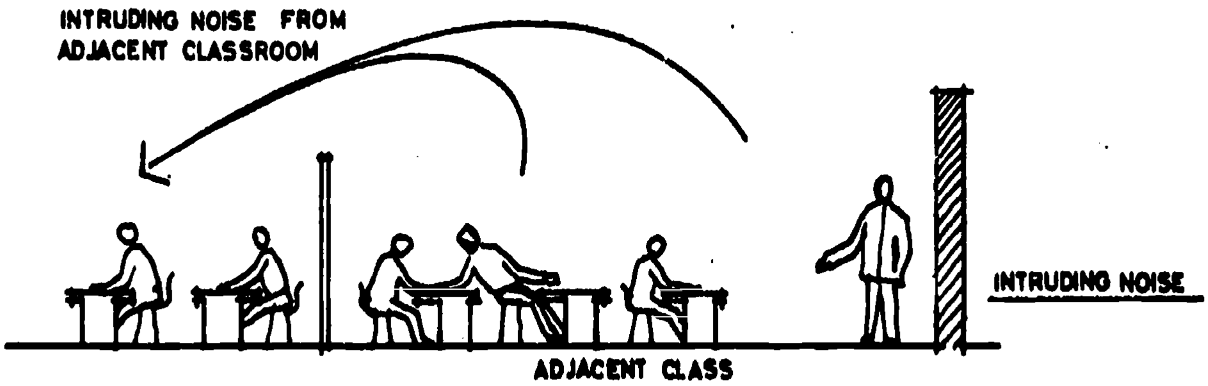


Figure 1 (c)

(iv) Background Noise: In any room, the internal and external noises combine to form what is known as background noise. Background noise exists everywhere and a certain amount of it is beneficial. For instance, the disturbance produced by intruding noise on the children in a classroom taking a lesson is somewhat reduced by the presence of background noise.

4. THEORY

(a) The acoustical condition of an individual classroom depends on the difference, in decibels, between the speech level and the background noise level. The speech articulation index Δ_1 is the ability to recognize speech components in the sound, such as might be heard in dictation given by a teacher. Since the intelligibility of the speech sounds depends upon their amplitude in various frequency bands, the speech articulation index would be a function of the difference in speech sound and the background noise at various frequency bands (and the importance of a particular band for speech sounds). The sound power level (db. re. 10^{-13}W) and importance function of normal speech are available in literature[2],[4]. Mathematically the speech articulation index can be expressed as:

$$\Delta_1 = \sum_{200\ \text{cps}}^{6000\ \text{cps}} (\Delta'_1 \times \text{I.F.})/6000$$

where Δ'_1 = (Speech Level - Noise Level) db.

The summation of (Δ'_1 x I.F.) covers all the sixteen 1/3 octave bands.

When two or more rooms are taken into consideration, the acoustical conditions depend upon the difference, in db. between the intruding speech level and the background noise. The intruding speech articulation index Δ_2 is an index of the ability to recognize the speech components from external intruding noise sources, such as TV sets or teacher/students in the adjoining room or space. Here also Δ_2 depends upon the difference in intruding sound and background noise at various frequency bands and the importance of a particular band for speech sounds. Mathematically, intruding speech articulation index can be expressed as:

$$\Delta_2 = \sum_{200\ \text{cps}}^{6000\ \text{cps.}} (\Delta'_2 \times \text{I.F.})/6000$$

where Δ'_2 = (Intruding Noise - Background Noise) db.

The summation of (Δ'_2 x I.F.) covers all the sixteen 1/3 octave bands.

(b) Noise Reduction: Laboratory measurement of noise reduction properties of any barrier is based on its sound transmission loss. The noise reduction is actually the contribution of sound from one area to another. It takes into consideration the area of the specific barrier, and also makes allowance for the effect of the acoustical environment in the listening room.

As in most of the cases in our survey, only a sound barrier of limited height and width is used between two teaching spaces. Typical sound barriers in teaching spaces are shown in Figures 2.(a) and 2.(b). Bending of sound at the edges or corners of a sound barrier is known as "diffraction". It is a common experience that considerable sound is propagated by diffraction around edges and corners. Sound transmission through a solid material (say 4-5 cm. thick) is quite low. What reaches the receiving side is mainly by diffraction. Decline in sound level as it travels from one point to another depends on the dimensions of the partitions.

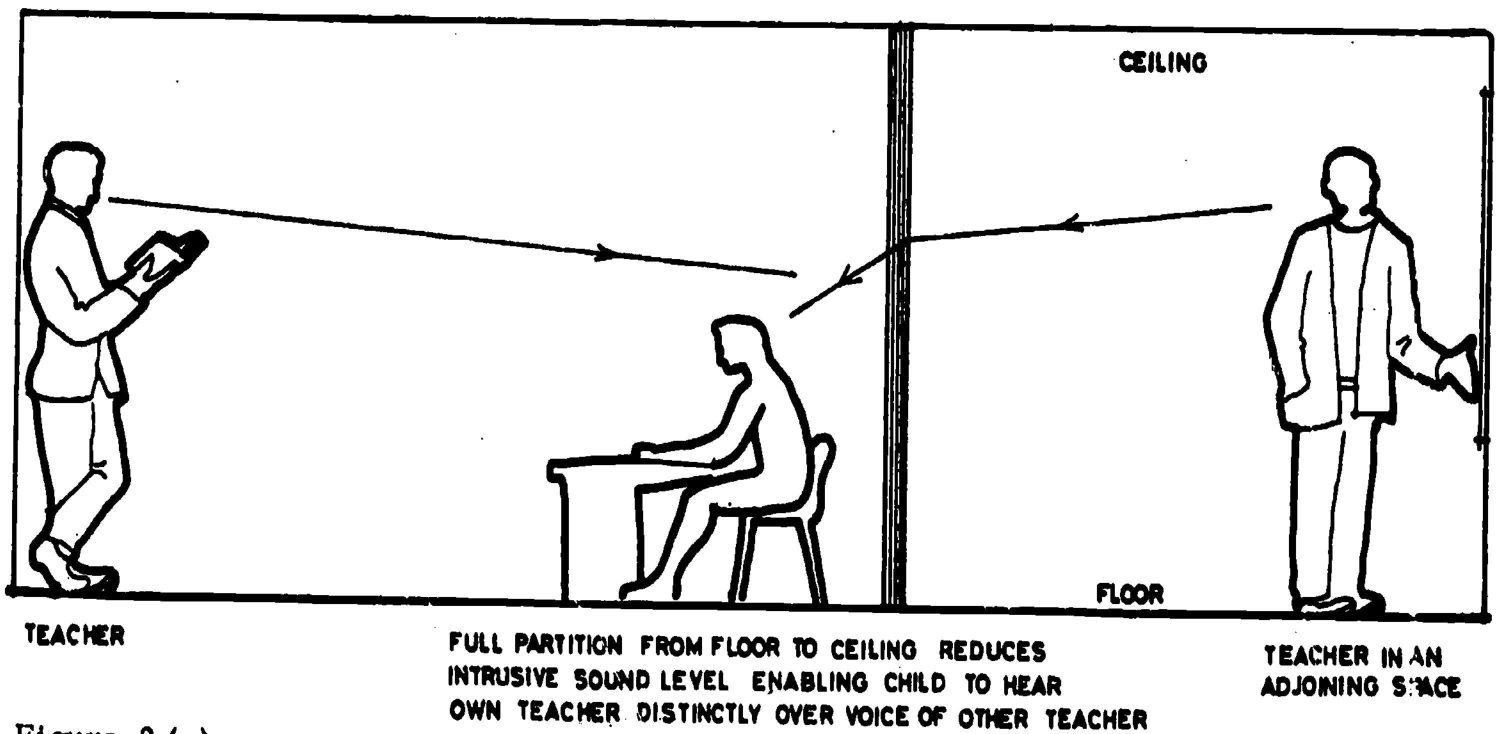


Figure 2 (a)

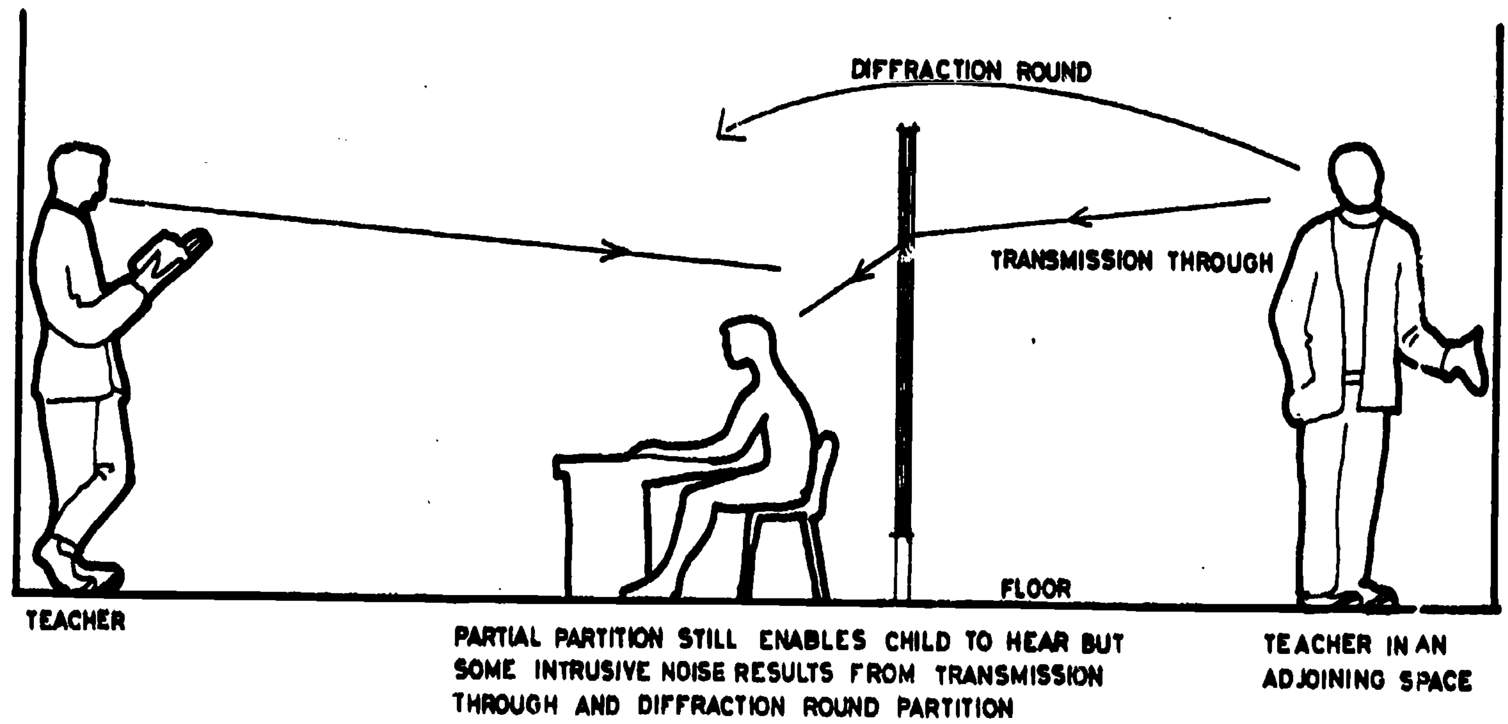


Figure 2 (b)

In actual practice the sound reduction experienced by a listener includes, in addition to the sound transmission loss of the partition, the effect of the area or areas of the boundary and the acoustical environment of the listening room. This combined effect is termed noise reduction in this study. Noise reduction may not be constant over all the audio-frequency bands. The frequency characteristics of noise reduction are therefore important features which have to be carefully determined.

(c) Reverberation: The classroom should not be too reverberant. If the room is too live (the term liveness refers to a condition of excessively prolonged reflections or reverberance), there will be difficulty in understanding what is said. This is because, if the rate of sound decay is so slow that one or more syllables persist in the room to the extent that they are in conflict, the listener has difficulty in separating them. In a reverberant room this prolongation of the sound applies not only to the speech originating with the specific classroom (in this case the wanted sound), but it applies also to any sound, whether from within the room itself or from the external sources, which may be in conflict with this wanted sound.

Thus a live room, that is to say, one that is excessively sound reflective, may be termed unsatisfactory. A group of prominent acousticians acting as a technical advisory committee for the Acoustical Materials Association, gave the optimum reverberation time for a particular space depending upon its volume as

$$T \text{ (seconds)} = \frac{\log_{10} V - 0.7}{2.5}$$

where V is the volume in m^3.

If the reverberation time measured at 500 cps. with 2/3 occupancy of room is nearly the same as the optimum time calculated using the above equation, then speaking and listening to speech should be found satisfactory.

5. NOISE AND NOISE REDUCTION

(a) The level of background noise is not steady, but fluctuates in a random manner. It is measured in decibels (dbA)[5, 6]. Noise levels around 50 dbA are quite common in classrooms, and teaching against such a low background level of noise would be found pleasant. While noise levels below 50 dbA provide a pleasant environment, those below 55 dbA are regarded as "not uncomfortable" for teaching. When the level of background noise exceeds 60 dbA and is sustained over a long period, it causes annoyance and distraction. It is also a common experience that tinny or shrill noise sounds are more disturbing than equally loud bass sounds.

When the level of background noise in classrooms with children quiet and busy at learning, rises above 60 dbA, noise reduction becomes necessary.

In the present survey, noise levels attained in the teaching spaces selected for study were recorded on the tape recorder for about five minutes. The overall noise level was simultaneously measured by a sound level meter. The recorded noise levels were then analysed at various 1/3 octave band frequencies for the calculation of the overall loudness value. From the phon levels in the one-third bands the overall loudness of noise was calculated by the usual procedure.

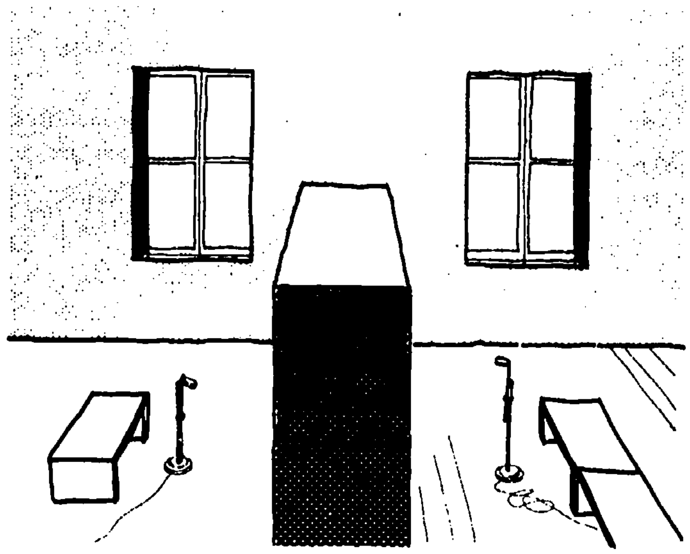


Plate 1. Arrangement for the measurement of noise reduction of partitions. The partition is the dark area in the centre of the photograph and the microphones are shown on either side of it.

Plate 1 shows the arrangement of the equipment for measurement of noise reduction by partition used between a pair of classrooms. Two microphones of the same type and identical characteristics are used. These are placed on either side of and near to the partition (about 50 cms). While noise is produced in the intruding room, recording of the noise is made simultaneously by the two microphones. The level of sound is also measured by sound level meter. The noise reduction of a partition was also measured for various locations of receiver and the source.

(b) For measurement of reverberation time, a series of 500 cps. warble tones were pre-recorded on a tape for 15 seconds duration each. Six bits of this recording were made in the laboratory. This tape was then replayed in the classroom where R. T. was to be measured. The teacher and children remained quiet during the measurements so that the noise level was low and the reverberant sound could decline through 30 db. or so. This reverberant sound and the decay was then recorded on another tape recorder. This final tape was then analysed in the laboratory with a high speed level recorder. The reverberation time of the classroom was found from the decay curves. The analytical arrangement is shown in Plate 2.

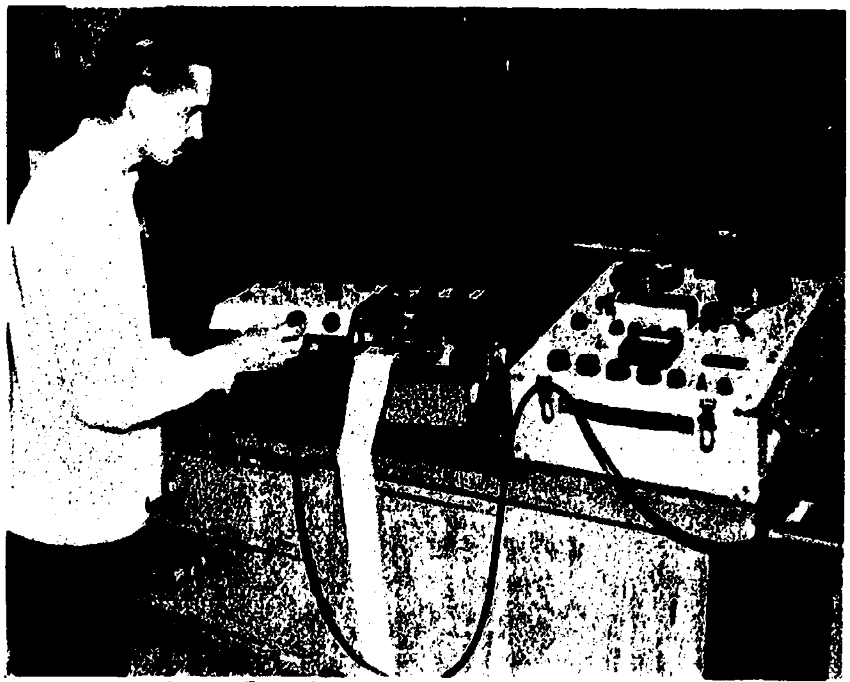


Plate 2. Arrangement for the analysis of reverberation time.

(c) Speech to noise ratio, is expressed in decibels (db) as the difference between the speech level and the background noise level. This is actually the ratio of pressure levels of speech sound and the noise level. It is this ratio, rather than the individual levels, on which the intelligibility of speech sound depends. Thus the intelligibility of speech of the teacher in a classroom depends upon the level of the background noise in the class. If the level of background noise is low, the intelligibility will be better than when the background noise level is high. There is an acceptable value of continuous background noise level in classrooms which is found just adequate for masking other interfering noises.

Plate 3 shows the experimental arrangement for the determination of speech articulation index Δ_1. The receiving microphone is placed in the centre of a group of students. A few students of good calibre are selected from the class and distributed in the room at various positions around the microphone. The ambient noise level, which continues a sample noise, is tape recorded for about five minutes. This sample noise is played back through another tape recorded and sound amplifying system at some prefixed levels. The background level and the speech level of the teacher at the position of the microphone are noted by the sound level meter. The levels were held constant for a particular measurement. Simultaneously the class teacher dictates some selected words to the students. This gives one value of speech articulation index and the corresponding number of errors made by the students. The noise level is then raised by about 3-4 db. by the amplifying system. Again a test is given to the students as explained above and the number of errors made by the students are counted. The experiment is repeated several times by raising the noise level in steps of 3-4 db in each measurement. From these measurements are calculated Δ_1 for different speech to noise ratios in the classroom and the corresponding percentage errors made by the students. Sometimes, students in neighbouring classrooms are asked to remain quiet so that the background noise level is decreased from its normal value and a test conducted in a situation much better than normally available in that classroom.

Plate 3. Experimental arrangement for the recording Δ_1.

Dictation to the children was given in their national/regional languages. Eight languages, Chinese, English, Hindi, Kankoni, Malay, Malayalam, Sinhalese and Tamil, were used in the four Asian countries in which the experiments took place. The words chosen for dictation were somewhat confusing in nature. In English for instance, the words were, hen, pen, men, run, fun, etc. The mistakes or the number of errors committed by the children are function of the speech to noise ratio prevailing in the classroom. In this set of experiments $\triangle_1$ was made to change by altering the noise level (speech level held constant). The percentage error made by the children for each set of noise level (for $\triangle_1$) is evaluated. Correlation is then sought between the percentage E and the measured values of $\triangle_1$. The correlation curve would prove or disprove whether the children are influenced, and if so what rate, by the acoustical environment of the classroom.

(d) The intruding sound to noise ratio is usually expressed in decibels as the difference between the intruding speech level and the background noise level. It is this ratio rather than the individual levels, on which the intelligibility of intruding speech depends. The effect of disturbance by intruding noise may be reduced by three processes:

(i) by limiting the entry of intruding noises into the classroom.

(ii) by raising to a reasonable level the background noises in the classroom.

(iii) by raising the speech level of the teacher.

As has already been mentioned, the level of the background noise should not be so high as unduly to diminish the difference between speech and noise level, reducing thereby the speech intelligibility. Furthermore, the background noise should not be low enough to form a large gap between intruding speech (and noise) as this may cause disturbance to the students. In the present set of measurements the background noise is kept constant at a comfortable level. By "comfortable level", is meant an acoustic environment in which the students commit the minimum number of mistakes. In most of the schools surveyed this level is the prevailing noise level in a classroom.

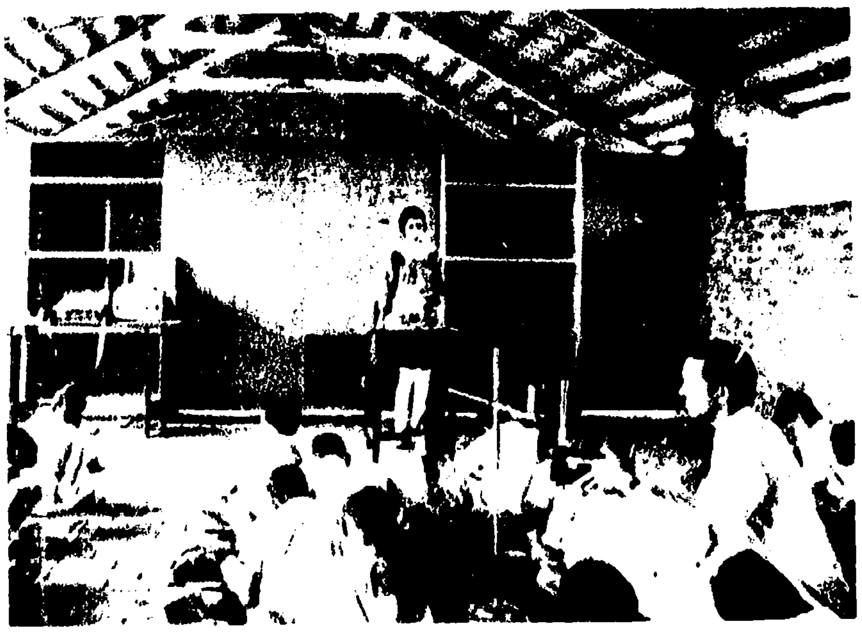


Plate 4. Experimental arrangement for the recording $\triangle_2$ in an Indian school designed by Architectural Division of the Central Building Research Institute, Roorkee, India.

There has to be a minimum difference in the levels of speech sound of the teacher and the intruding sound. Thus the speech level of the teacher cannot be very high or very low. In the experiment on the effect of intruding noise, the speech level of the teacher was also held steady.

Plate 4 shows the arrangement of the equipment for the determination of intruding speech articulation index $\triangle_2$. For this measurement, a sample of intruding sound from an adjacent teacher or classroom is first recorded. This intruding sound is then replayed at varying intensities in the classroom under test. The voice level of the teacher giving dictation to the children, the replayed intruding sound at a controlled and desired level, also the background noise level were all picked up by the receiving microphone and recorded on a second tape recorder. The teacher in the receiving room was then asked to give dictation to the under normal conditions of intruding sound. The receiving microphone was again kept at the same place as in the case of speech articulation index. A number of measurements are conducted by raising the intruding sound in steps of 3-4 db. This allowed determination of the values of $\triangle_2$ and calculation of the percentage error by the students subjected to, not only normal but also the raised levels of intruding sound, in the classroom. As before, the subjective effect of the intruding noise was determined by giving dictation to the children of some typical words chosen to determine the corresponding errors committed by the students subjected to different degrees of interfering noises.

The number or errors made by the children is dependent on the ratio of intruding noise to background noise in the classroom. The percentage error is also dependent on the ratio of speech sound to intruding sound. Since the speech level in these tests is held constant and the intruding level varies, an evaluation of the acceptable value of $\triangle_2$ will lead to the determination of the acceptable ratio of speech to intruding sound. In this set of experiments, $\triangle_2$ was made to change by altering the intruding noise level (speech level held constant). The percentage error made by the children for each set of intruding noise levels (or $\triangle_2$) was evaluated. Correction was then sought between the percentage error E and the measured value of $\triangle_2$. The existence or otherwise of correlation would prove or disprove whether the children are influenced and if so, at what rate, by the acoustical environment of the classroom.

6. ANALYTICAL PROCEDURE

Data on the tapes were subjected to spectral analysis in the C.B.R.I. laboratory using an audio-frequency spectrometer. The arrangement for analysis is shown in Plate 5. The analysis of background noise was made for its average value in different frequency bands. The indicating meter of the spectrometer was put on the position "slow". It is recognized that the intelligibility of speech and intruding sound depend on their peak values. The peaks cannot be exactly registered by the indicating instrument, although the position "high speed" was employed for peak reading. It is observed that the peaks are about 6 db higher than the peaks recorded by fast acting meters. Hence 6 db is added in the measured speech level to obtain the peak loudness of speech. In the ratio S/N, S is the loudness of the speech and N is the dbA level of background noise.

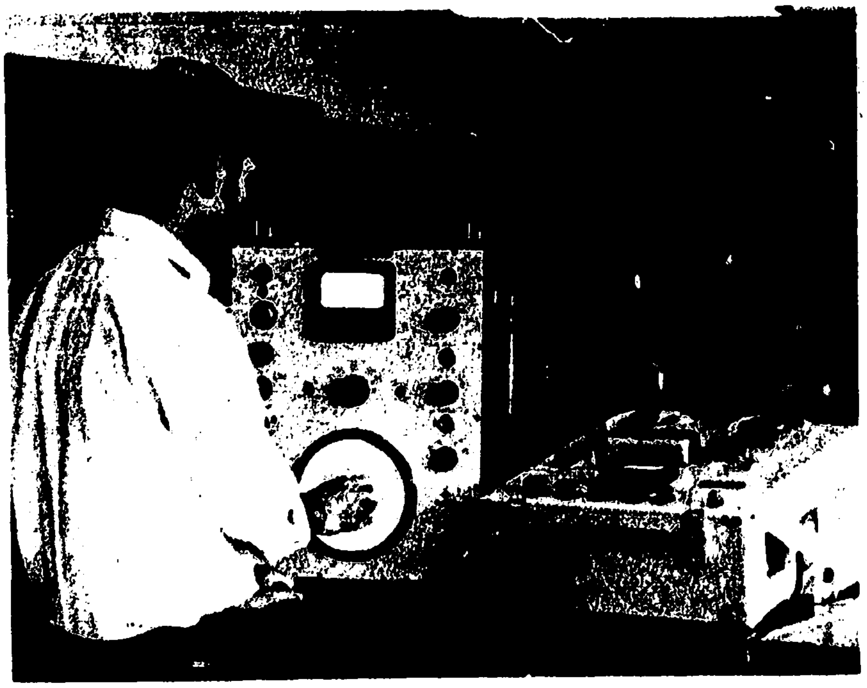


Plate 5. Arrangement for the analysis of $\triangle_1$ and $\triangle_2$ in the CBRI acoustics laboratory.

Three data sheets were prepared in which the results of the analyses were entered. Typical data sheets A, B and C are shown (in Appendices A, B, C). Data sheet A is for the analysis of background noise and speech levels. Each set of measurements is entered in one sheet. The method of calculation of $\triangle_1$ from the recorded data is as follows. In column 2, the spectral distribution of long time recording of background noise level is given. The corresponding values of loudness at various bands are given in column 3. In columns 4 and 6, the band spectrum data are given for background noise and speech sounds, the corresponding values of loudness in sones are given in columns 6 and 7. Differences between values in columns 6 and 4 are given in db. in column 8. This is symbolised as $\triangle_1$. Values of importance functions (IF) at various frequency bands are given in column 9. $\triangle_1$ in each band multiplied by the corresponding IF, are given in the last column, 10. The sum of the products $\triangle_1$ x IF is divided by 6000 to derive the resultant $\triangle_1$. Finally, calculation of $\triangle_1$ from the recorded data is shown towards the end of the sheet, which also shows the calculation of the loudness levels, S. These levels also are required to determine accurately the ratio of speech to noise. The average number or errors made by the students for the background noises and speech noises given in the sheet are shown at the bottom right-hand corner of the data sheet. An indication is also given whether the dictation was in words or in sentences.

Data sheet B is for the analysis of intruding noise and speech sounds. The values of $\triangle_2$ are calculated in the same fashion as for $\triangle_1$. The average values of the number of mistakes committed by the children when subjected to sets of particular background noise, intruding noise and the speech sound, are given on the right side of the sheet.

Data sheet C is for determining noise reduction. White noise recorded in the source room and in the receiving room was analysed in 1/3rd octave bands. The noise level in db. in each band is converted to the corresponding sone levels. The difference between the results in columns 2 and 4 gives the spectral noise reduction. The "sone" values in columns 3 and 5 are used to find the loudness of the noise (a very important parameter) in the source room and the receiving room. The overall reduction in the loudness of noise due to the partition is shown at the end.

Analysis of a survey which is so extensive and complex is a very difficult task. It is, of course, necessary that it is done as objective as possible. Yet, there is always the danger that subjective opinion and reaction may influence any conclusions that may be reached. It is almost impossible to keep objective measurements such as those of the background level and the speech level of the teacher constant. It is for this reason that a mean curve was drawn through the plots of the S/N ratio and the corresponding (calculated) values of $\triangle_1$. It is observed in each school that S/N is lineally related to the speech articulation index $\triangle_1$. From this curve, the corrected values of $\triangle_1$ and the percentage error made by the students is then drawn.

Because of the variations in the level of intruding noise and the background noise, during measurements, a mean line was likewise drawn between the plots of the IS/N ratio and the corresponding (calculated) values of Δ_2. From this curve the corrected values of Δ_2 were obtained. A curve was then drawn between this corrected Δ_2 and the percentage error of the students. Finally, the percentage error E, corresponding to any particular value of Δ_2 was noted from this curve.

In the test for Δ_2 which is dependent on intruding noise, the speech level of the teacher in the test room should be constant. The number of mistakes would change if the speech level changed during the experiment. When such variations did exist in and when they were different from, that in the experiment for Δ_1, a curve could be drawn between S/IS and the number of mistakes. This would lead to the exact number of mistakes which would have been otherwise committed by the students if the speech level for Δ_2 had been the same as that in the case of Δ_1. The curve for a typical case is given in Figure 3.

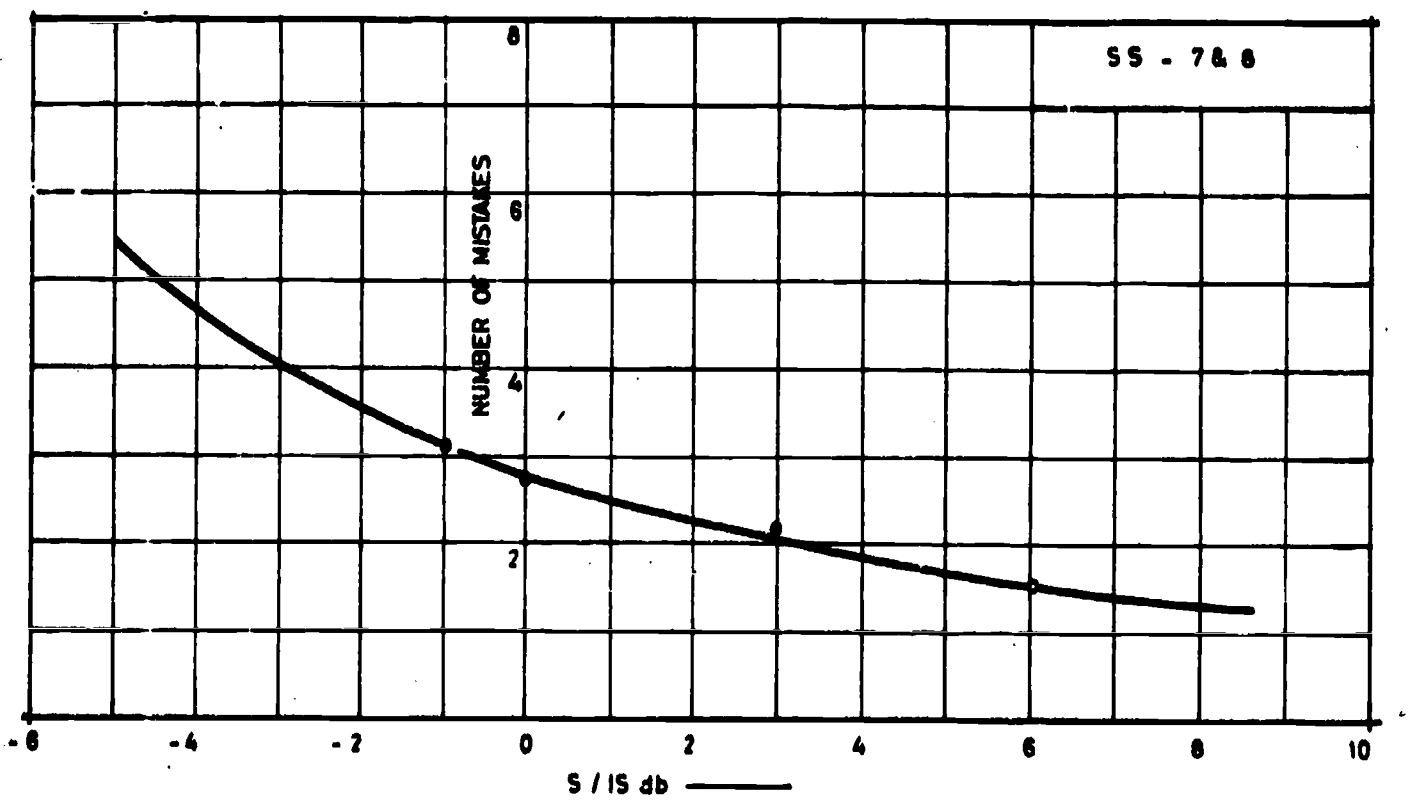


Figure 3

7. RESULTS

(a) The noise reduction (NR) across the partition was measured by producing white noise in the intruding room and the levels of noise were measured immediately on both sides of the partitions. The noise reduction of partitions was also measured for various locations of the source and receiver in the test room. The values of noise reduction in the India school shown in Figure 4 are shown in Figures 5-10 inclusive.

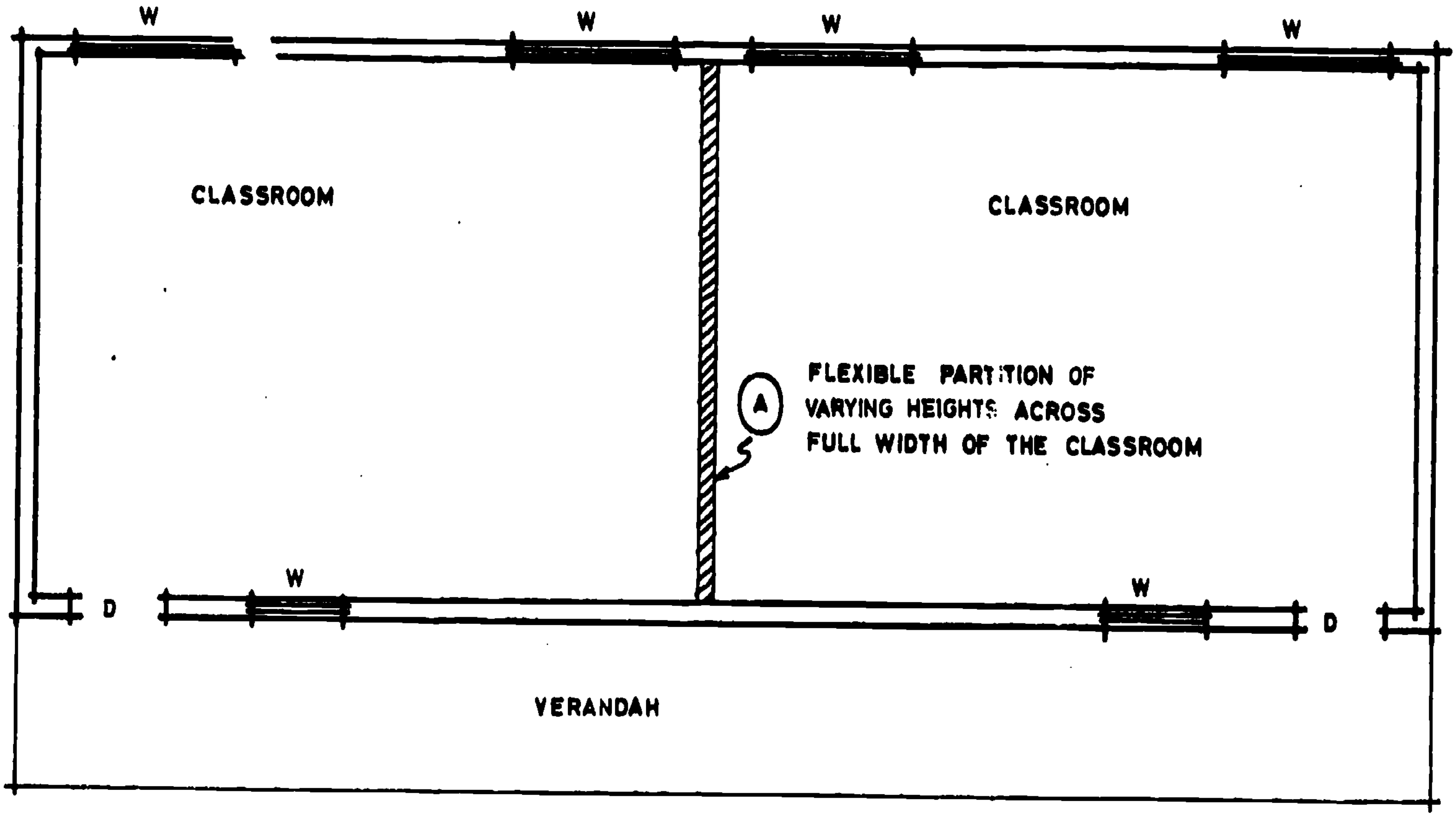


Figure 4

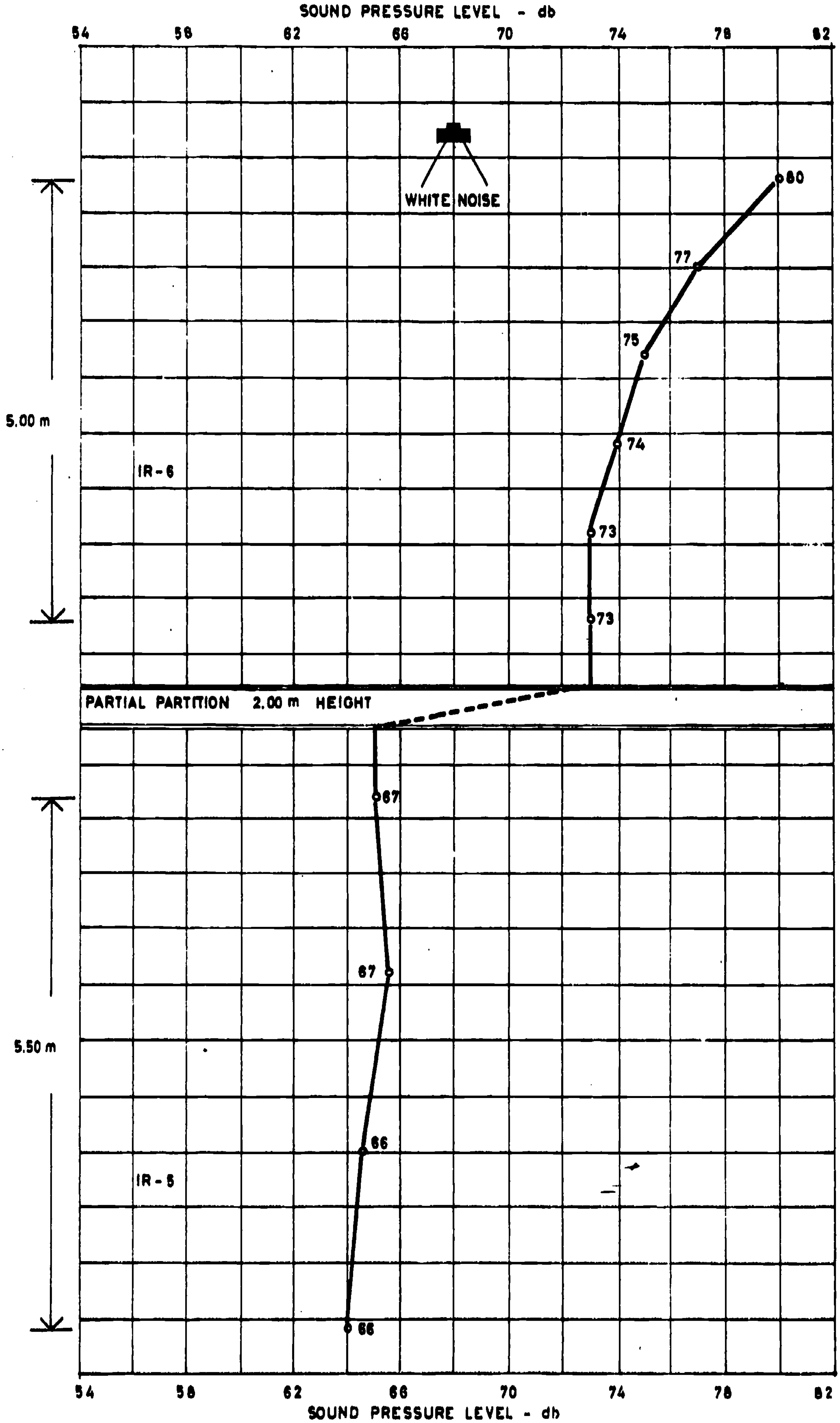

SOUND PRESSURE LEVEL - db
54
58
62
66
70
74
78
82
WHITE NOISE
80
77
75
74
73
73
5.00 m
IR - 6
PARTIAL PARTITION 2.00 m HEIGHT
67
67
66
66
5.50 m
IR - 5
54
58
62
66
70
74
78
82
SOUND PRESSURE LEVEL - db

Figure 5

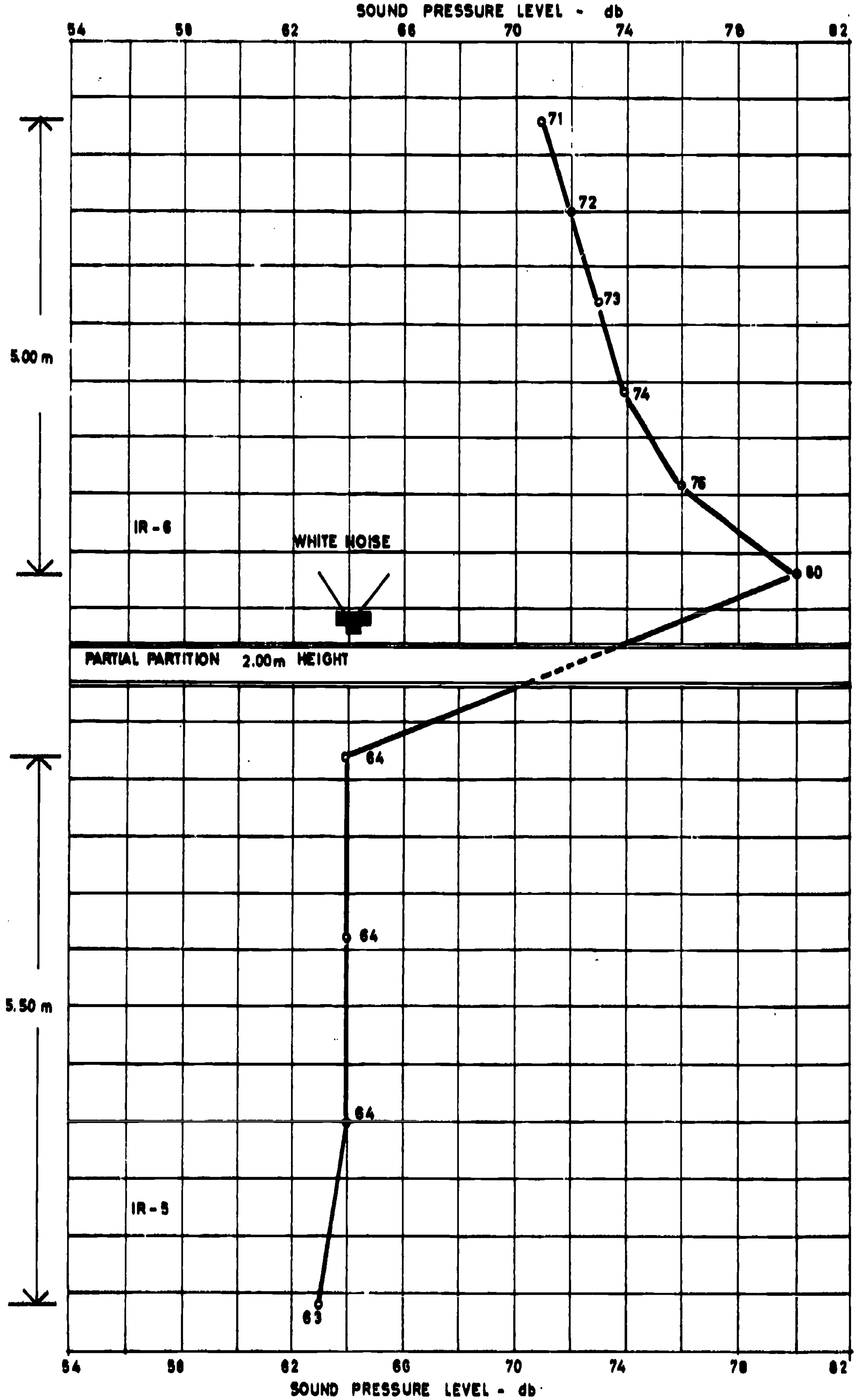

SOUND PRESSURE LEVEL - db
54
58
62
66
70
74
78
82
5.00 m
IR - 6
WHITE NOISE
71
72
73
74
76
80
PARTIAL PARTITION 2.00m HEIGHT
64
64
64
63
5.50 m
IR - 5

Figure 6

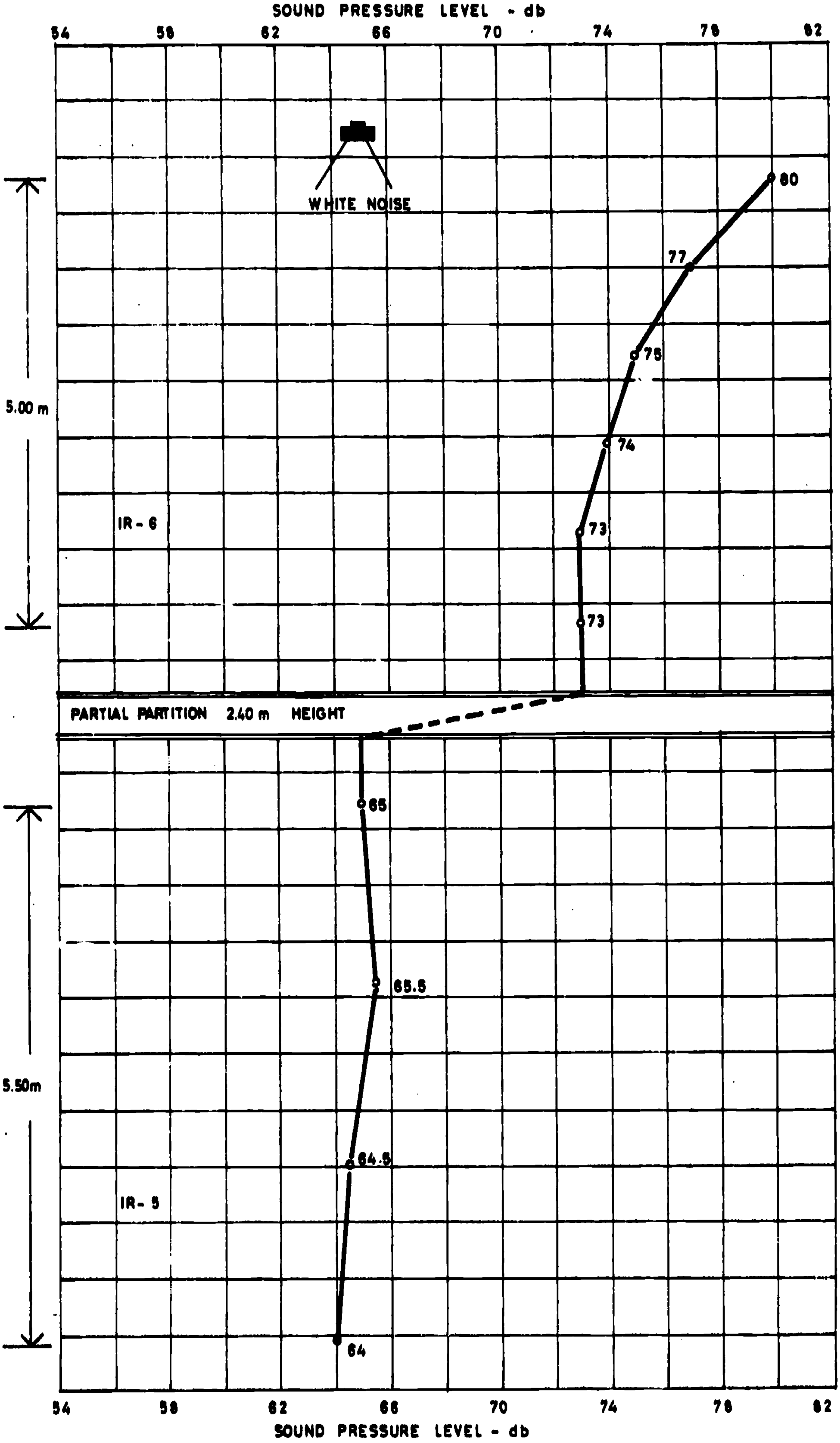

SOUND PRESSURE LEVEL - db
54
58
62
66
70
74
78
82
WHITE NOISE
80
77
75
74
73
73
5.00 m
IR - 6
PARTIAL PARTITION 2.40 m HEIGHT
65
65.5
64.5
64
5.50m
IR- 5
SOUND PRESSURE LEVEL - db

Figure 7

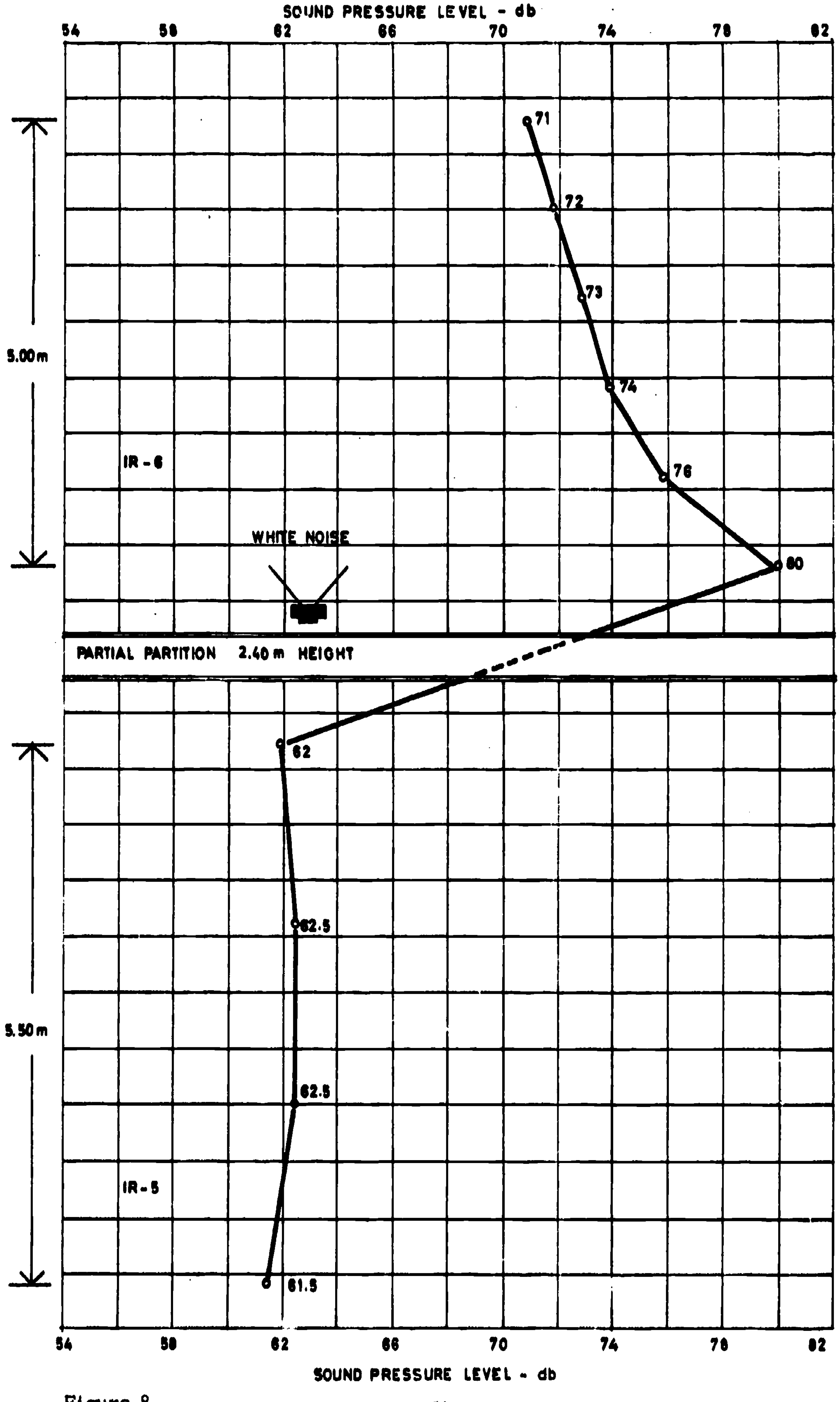

SOUND PRESSURE LEVEL - db
54
58
62
66
70
74
78
82
71
72
73
74
76
80
5.00 m
IR - 6
WHITE NOISE
PARTIAL PARTITION 2.40 m HEIGHT
62
62.5
62.5
61.5
5.50 m
IR - 5
SOUND PRESSURE LEVEL - db

Figure 8

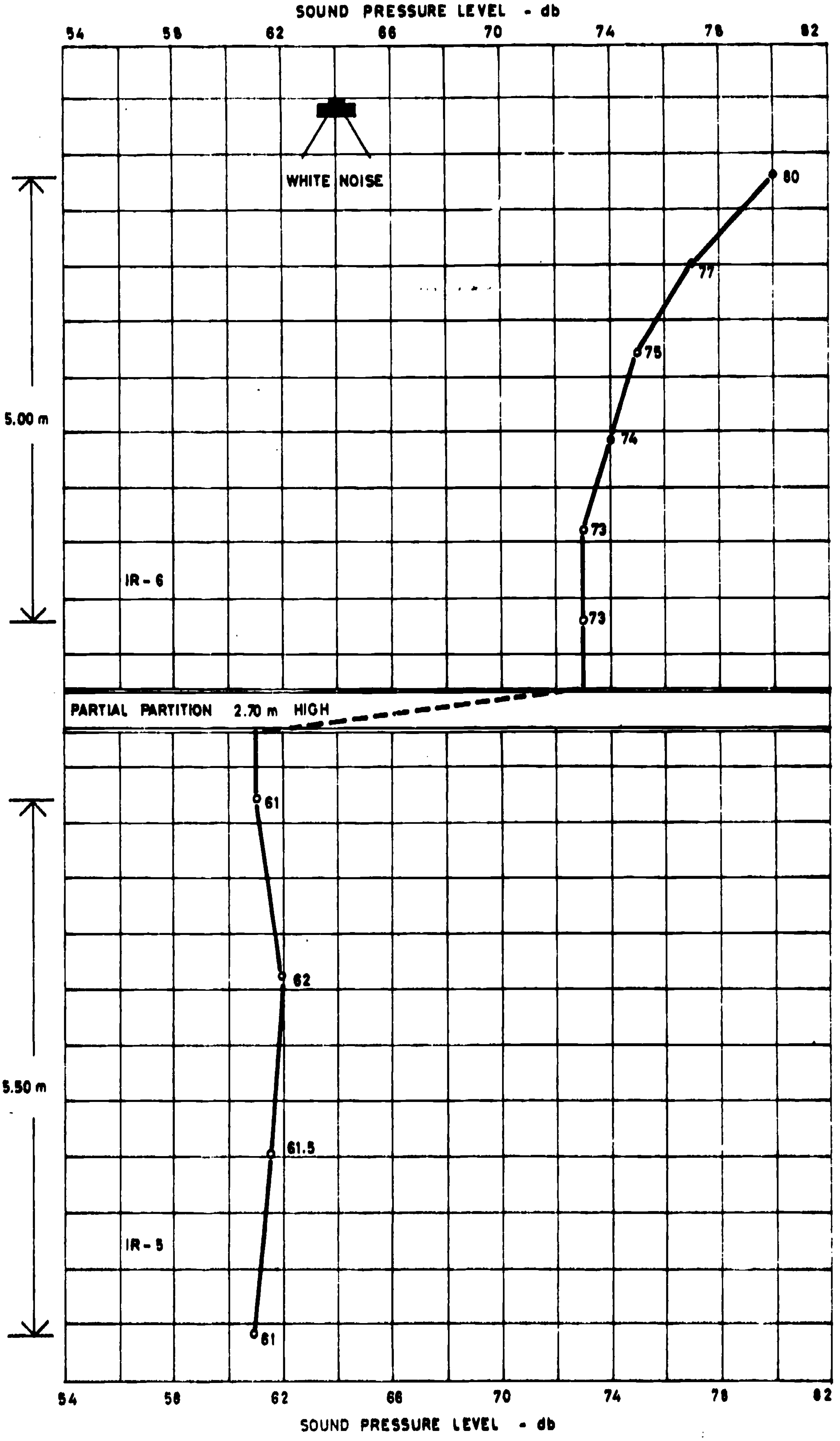

SOUND PRESSURE LEVEL - db
54
58
62
66
70
74
78
82
WHITE NOISE
80
77
75
74
73
73
5.00 m
IR - 6
PARTIAL PARTITION 2.70 m HIGH
61
62
61.5
61
5.50 m
IR - 5
54
58
62
66
70
74
78
82
SOUND PRESSURE LEVEL - db

Figure 9

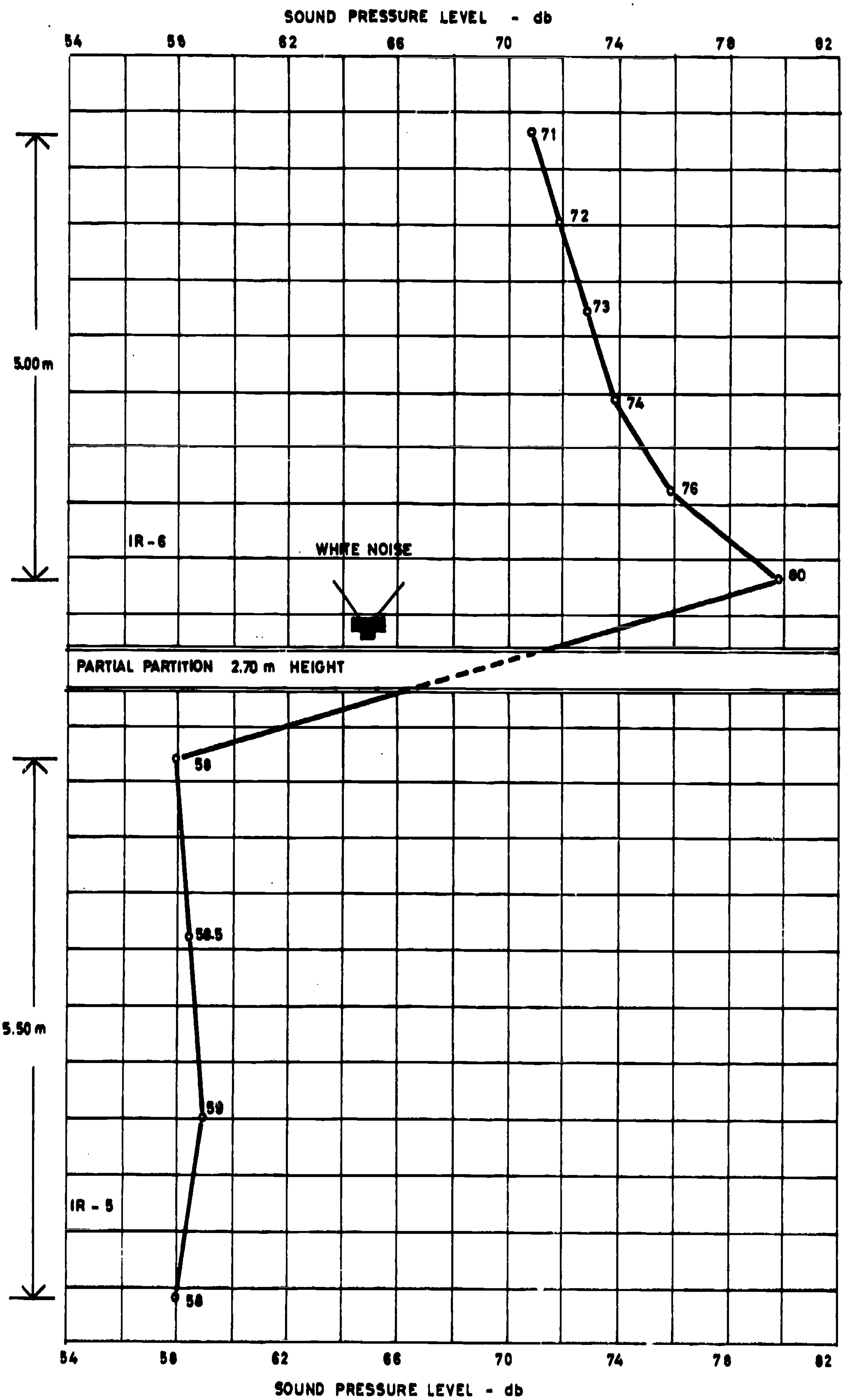

SOUND PRESSURE LEVEL - db
54
58
62
66
70
74
78
82
71
72
73
74
76
80
5.00 m
IR - 6
WHITE NOISE
PARTIAL PARTITION 2.70 m HEIGHT
58
58.5
59
58
5.50 m
IR - 5
SOUND PRESSURE LEVEL - db

Figure 10

TABLE I

SUMMARY CHART	SRI LANKA 1 CG-1 & 2	2 CC-3 & 4	3 CC-5 & 6	4 CC-7 & 8	5 CH-9 & 10	6 CD-11 & 12	7 CD-13 & 14	8 CC-15 & 16	9 CC-17 & 18	INDIA 1 IG-1 & 2	2 IG-3 & 4	3 IG-5 & 6	4 IG-7 & 8	5 IG-9 & 10	6 IK-1 & 2	7 IK-3 & 4	8 IK-5 & 6	9 IR-1 & 2	10 IR-3 & 4	11 IR-5 & 6	12 IR-7 & 8	MALAYSIA 1 MP-1,2 & 3	2 MK-4 & 5	3 MK-6 & 7	4 MK-8 & 9	5 MJ 10 & 11	6 MK-12 & 13
BACKGROUND NOISE LEVEL, db.	58	-	60	60	57	56	59	60	60	58	60	57	56	58	59	56	60	57	58	58	57	65	58	60	-	59	5
SPEECH LEVEL OF TEACHER AT 3 METRES, db.	73	-	73	73	68	70	72	74	74	62	66	68	64	64	66	65	68	63	62	62	64	76	72	72	-	63	7
INTRUDING SPEECH LEVEL, db.	67	-	64	66	58	64	68	65	68	64	65	65	62	63	65	65	65	-	59	60	58	65	61	62	-	65	6
SPEECH ARTICULATION INDEX, Δ_1 UNDER NORMAL CONDITIONS	.56	-	.30	.37	.26	.34	.37	.34	.37	.20	.15	.20	.31	.20	.33	.23	.22	.21	.16	.16	.19	.21	.41	.32	-	.17	.4
ERRORS PERCENT UNDER NORMAL S/N RATIO	2.2	-	3.3	3.3	12	3.3	6.5	3.5	13	12	17	14	10	16	12	14	16	13	15	13	13	14	1.0	13	-	13	4.
INTRUDING SPEECH ARTICULATION INDEX, Δ_2 UNDER NORMAL COND.	.19	-	.09	.15	.06	.17	.15	.12	.15	.16	.09	.22	.18	.17	.19	.17	.06	-	.08	.06	.07	.04	.03	.14	-	.02	.1
ERRORS PERCENT UNDER NORMAL I S/N RATIO	6.6	-	3.3	3.5	10	16	18	7.5	16	23	18	22	17	18	24	24	17	-	4.5	7.0	6.6	7.0	3.5	13	-	40	12
NOISE REDUCTION, db.	-	15	17	14	18	11	10	21	9	11	10	10	7	9	12	17	7	24	13	12	15	13	10	13	-	12	1
OPTIMUM REVERBERATION TIME, T, Sec.	.65	.86	.58	.62	.54	.64	.61	.59	.60	.52	.60	.59	.56	.55	.54	.59	.54	.58	.60	.61	.60	.64	.63	.63	.64	.63	.6
MEASURED REVERBERATION TIME T, Sec.	-	-	-	-	.85	.70	.70	.65	1.0	-	-	-	-	-	-	-	-	.83	1.0	.73	.93	.60	.50	.70	.50	.50	.5

BEST COPY AVAILABLE

TABLE I

)		1	2	3	4	5	6	7	8	9	10	11	12		1	2	3	4	5	6	7		1	2	3	4	5	6	7
CC-17 & 18	INDIA	IG-1 & 2	IG-3 & 4	IG-5 & 6	IG-7 & 8	IG-9 & 10	IK-1 & 2	IK-3 & 4	IK-5 & 6	IR-1 & 2	IR-3 & 4	IR-5 & 6	IR-7 & 8	MALAYSIA	MP-1, 2 & 3	MK-4 & 5	MK-6 & 7	MK-8 & 9	MJ 10 & 11	MK-12 & 13	MS-14 & 15	SINGAPORE	SS-1 & 2	SS-3 & 4	SS-5 & 6	SS-7 & 8	SS-9 & 10	SS-11 & 12	SS-13 & 14
0		58	60	57	56	58	59	56	60	57	58	58	57		65	58	60	-	59	58	55		69	64	59	64	60	59	64
4		62	66	68	64	64	66	65	68	63	62	62	64		76	72	72	-	63	72	74		63	67	64	67	68	68	72
8		64	65	65	62	63	65	65	65	-	59	60	58		65	61	62	-	65	66	64		64	65	60	65	61	58	60
7		.20	.15	.20	.31	.20	.33	.23	.22	.21	.16	.16	.19		.21	.41	.32	-	.17	.41	.56		.31	.35	.23	.26	.40	.29	.34
3		12	17	14	10	16	12	14	16	13	15	13	13		14	1.0	13	-	13	4.0	6.6		8.0	9.0	8.0	9.5	2.0	6.0	6.0
5		.16	.09	.22	.18	.17	.19	.17	.06	-	.08	.06	.07		.04	.03	.14	-	.02	.16	.22		.31	.16	.10	.20	.23	.10	.05
6		23	18	22	17	18	24	24	17	-	4.5	7.0	6.6		7.0	3.5	13	-	40	12	11		20	10	6.5	11	14	7.0	6.0
9		11	10	10	7	9	12	17	7	24	13	12	15		13	10	13	-	12	15	9			18	22	17	28	20	12
0		.52	.60	.59	.56	.55	.54	.59	.54	.58	.60	.61	.60		.64	.63	.63	.64	.63	.64	.59		.64	.63	.66	.61	.63	.63	.58
9		-	-	-	-	-	-	-	-	.83	1.0	.73	.93		.60	.50	.70	.50	.50	.55	.60		.75	.67	.67	.57	.75	.70	-

(b) The results of the measurements of <u>noise level</u> in various schools are summarised in Table 1.

(c) The <u>speech level</u> of the teacher was measured at a distance of about 3 metres from his/her mouth by a sensitive microphone placed amidst a group of subjects who were selected for taking down dictation. The measured speech levels of the teacher are summarized in Table 1.

A typical mean curve between S/N ratio and $\triangle_1$ for a particular school (S.S-9 & 10) is shown in Figure 11 from which the corrected values of $\triangle_1$ are found. The resultant curve between corrected $\triangle_1$ and the percentage error is shown in Figure 12. It is clear from the curve that as the value of $\triangle_1$ decreases, the percentage error of the students goes on increasing. It can be shown by extrapolation of the curve that for very low values of $\triangle_1$, the percentage error may be one hundred percent, but for very high values of $\triangle_1$ there are residual errors. In most of the cases for very high values of $\triangle_1$, the errors are about five percent.

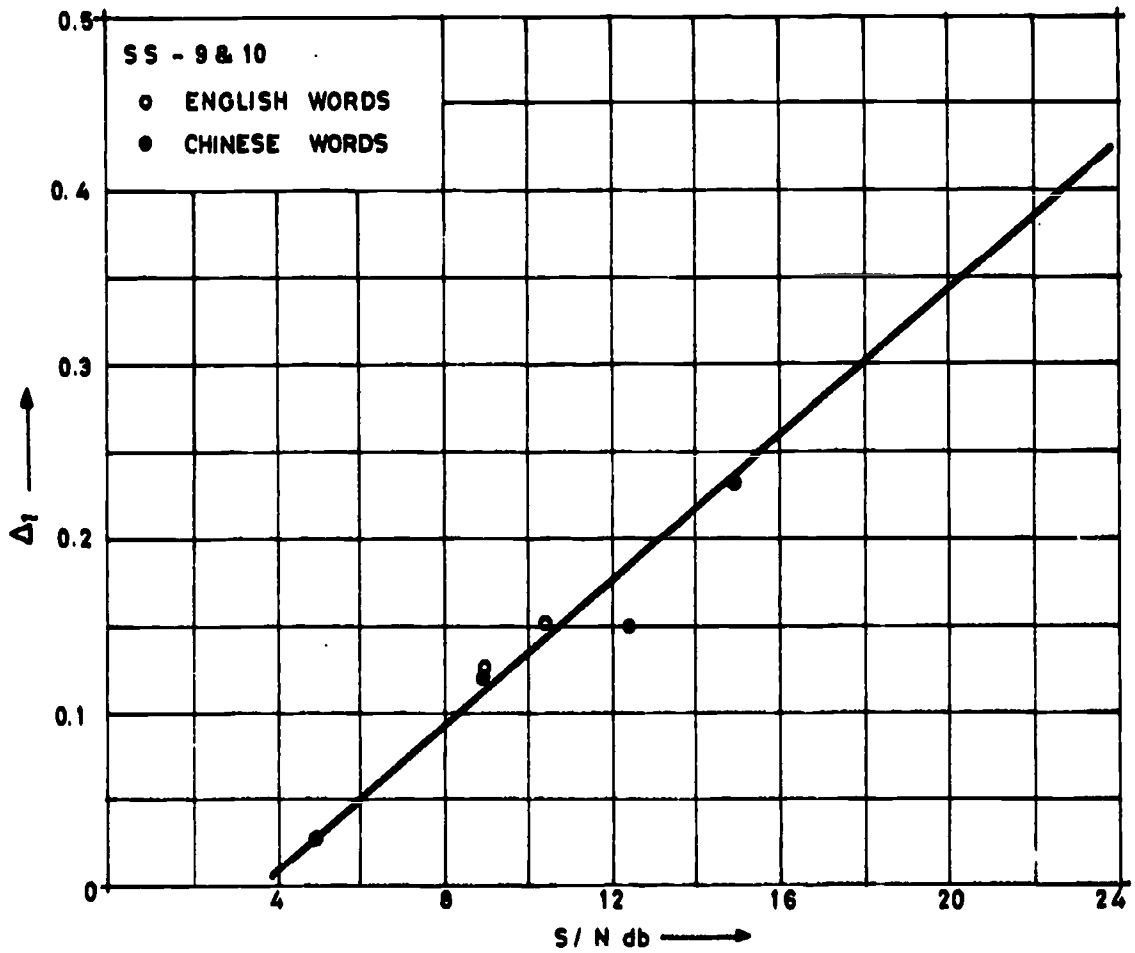


Figure 11

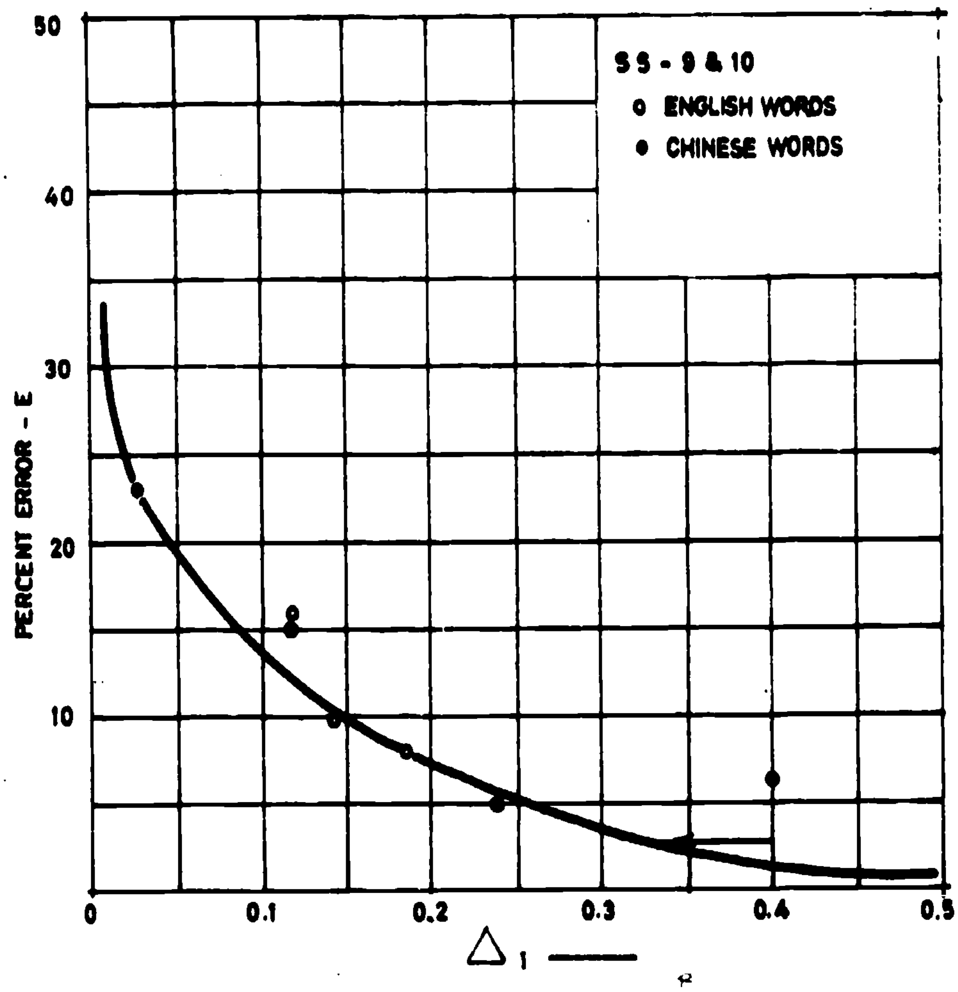


Figure 12

These basic or minimum, five percent errors are always made by the students; this may not be due to bad acoustical conditions but may be attributed to other reasons such as lack of attention, or imperfect hearing acuity. Finally, the percentage error E corresponding to a particular value of Δ_1 was obtained. Values for a particular school (SS-9 & 10) by this procedure are shown in Tables 2 and 3.

Finally, as shown in Figures 13 to 16, the values of Δ_1 and E for all the schools in a country were plotted. The data relating to E with Δ_1 for each country were fed into a digital computer to evaluate a correlation curve between E and Δ_1. The equation of the curve was assumed to be a polynomial of the second degree, i.e.

$$E = A \Delta_1^2 + B \Delta_1 + C$$

The result of this computation is shown by the curves in Figures 13 to 16. The correlation coefficient (γ) of each curve was also computed. The equation derived and the correlation coefficients are noted beside each curve. It is observed that coefficients exceed 0.8 which establishes a correlation of high degree between E and Δ_1.

Table 2. Derivation of speech to noise ratio for the schools S. S. 9 and 10

Sound Level Meter (A)		Add 6 db. S. L. peak	Loudness Phon S. L. peak	Estimated mean of (3) and (4) S	S/N (5) - (1)
N. L.	S. L.				
(1)	(2)	(3)	(4)	(5)	(6)
52	68.0	74.0	75.0	74.5	22.5
50	60.0	66.0	64.5	65.0	15.0
62	68.0	74.0	75.0	74.5	12.5
68	73.0	79.0	78.0	78.5	10.5
72	75.0	81.0	81.5	81.0	9.0
62	65.0	71.0	71.0	71.0	9.0
66	65.0	71.0	71.0	71.0	5.0
71	65.0	71.0	71.0	71.0	0.0

Table 3. Percentage error for different values of Δ_1 for schools S. S. 9 and 10

S/N	Calculated Δ_1	Corrected Δ_1	Percent error E
22.5 E	0.40	0.40	2.0
15.0 CH	0.23	0.24	5.0
12.5 E	0.149	0.185	8.5
10.5 E	0.152	0.145	11.0
9.0 E	0.125	0.120	12.5
9.0 CH	0.121	0.120	12.5
5.0 CH	0.027	0.027	26.0

E means English language
CH means Chinese language

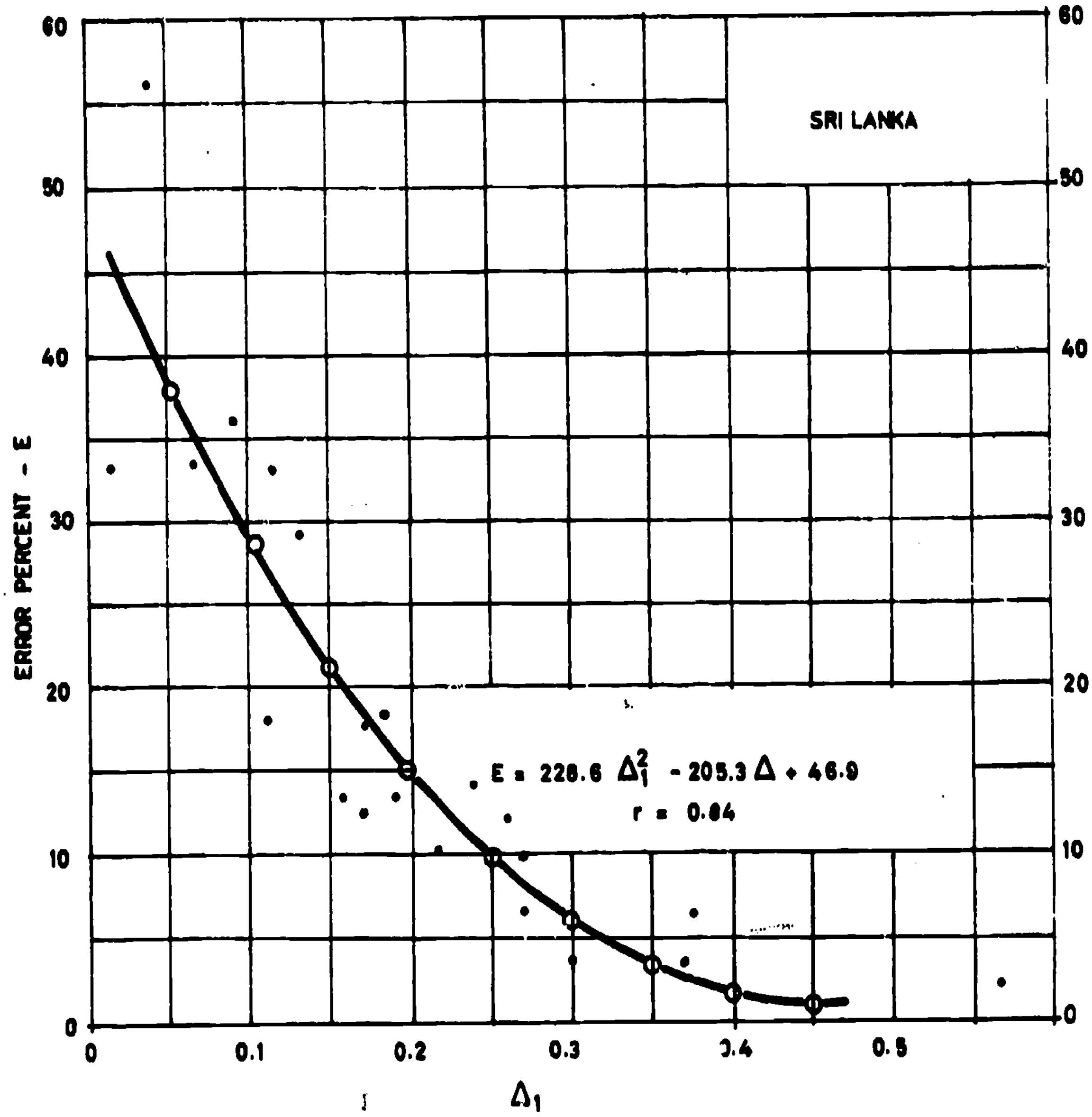
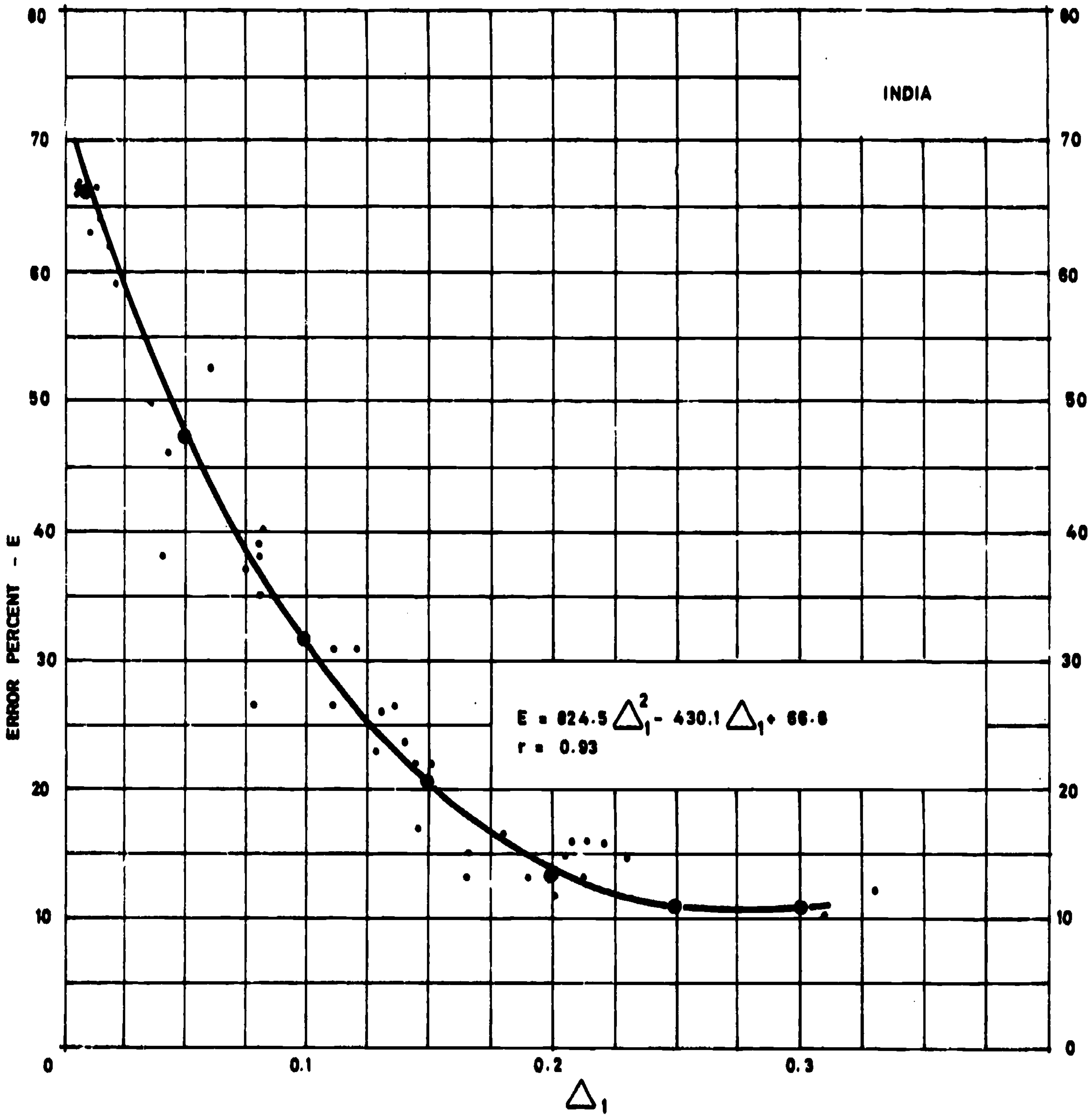
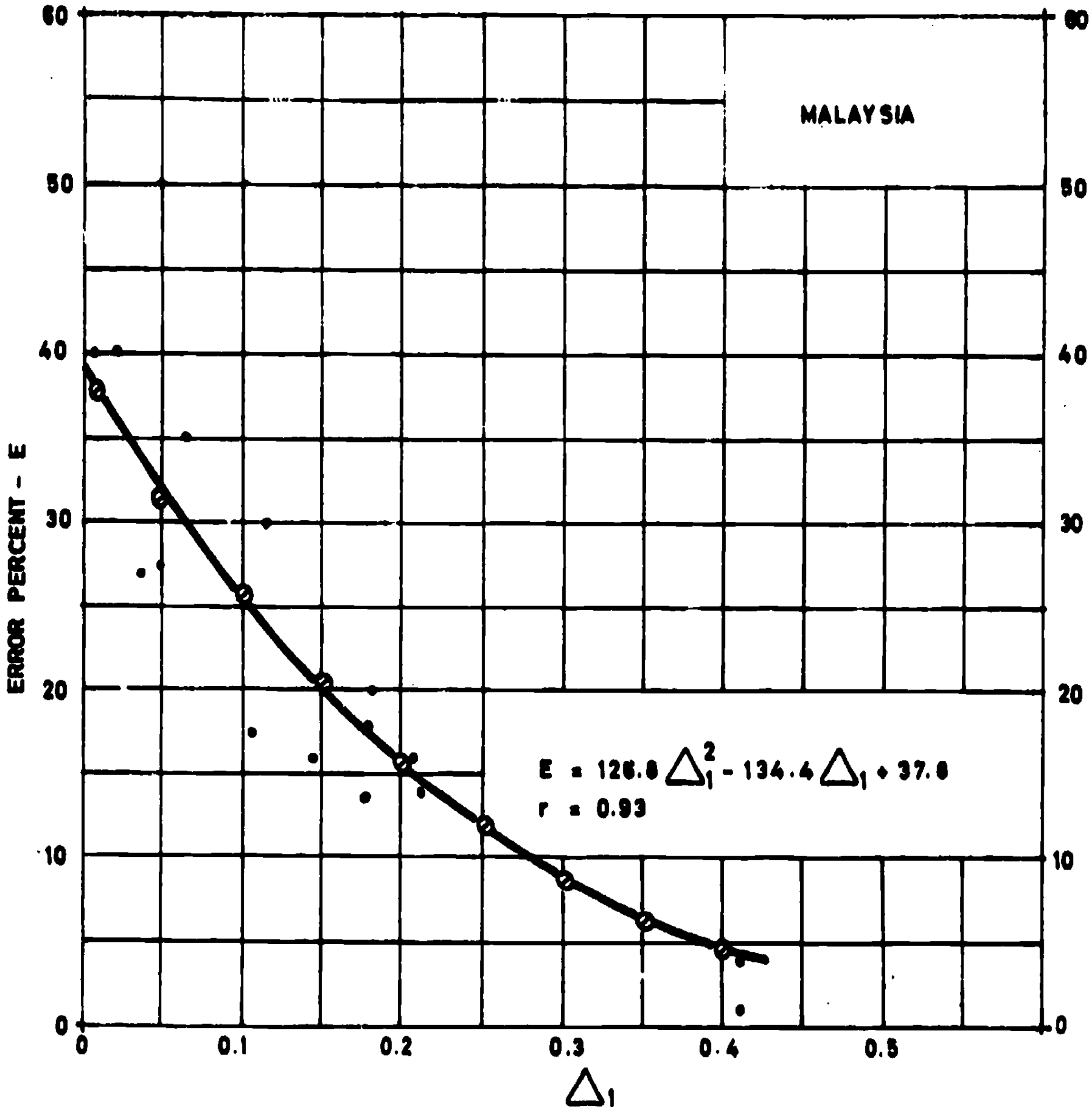

SRI LANKA
ERROR PERCENT - E
E = 228.6 Δ²₁ - 205.3 Δ + 46.9
r = 0.84
Δ₁
0
0.1
0.2
0.3
0.4
0.5
10
20
30
40
50
60

Figure 13



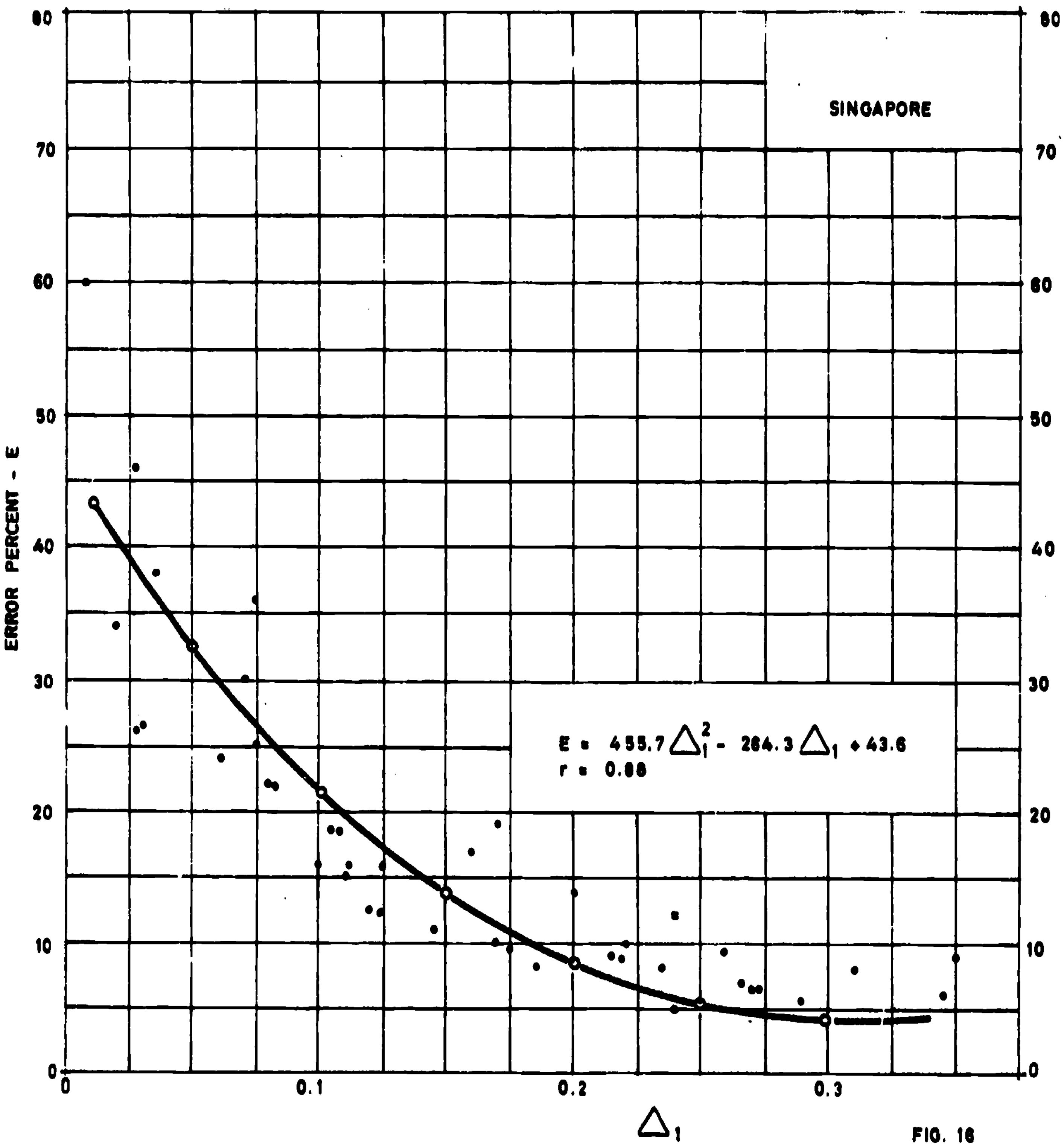
INDIA
E = 824.5 Δ_1^2 - 430.1 Δ_1 + 66.8
r = 0.93
ERROR PERCENT - E
Δ_1
0
0.1
0.2
0.3
10
20
30
40
50
60
70
80

Figure 14



MALAYSIA
ERROR PERCENT - E
60
50
40
30
20
10
0
0.1
0.2
0.3
0.4
0.5
Δ_1
$E = 126.8\,\Delta_1^2 - 134.4\,\Delta_1 + 37.8$
$r = 0.93$

Figure 15



SINGAPORE
ERROR PERCENT - E
$E = 455.7 \Delta_1^2 - 264.3 \Delta_1 + 43.6$
r = 0.88
Δ_1
FIG. 16

Figure 16

Similarly a mean curve for intruding speech is drawn between Δ_2 and IS/N ratio. A typical curve is shown in Figure 17.

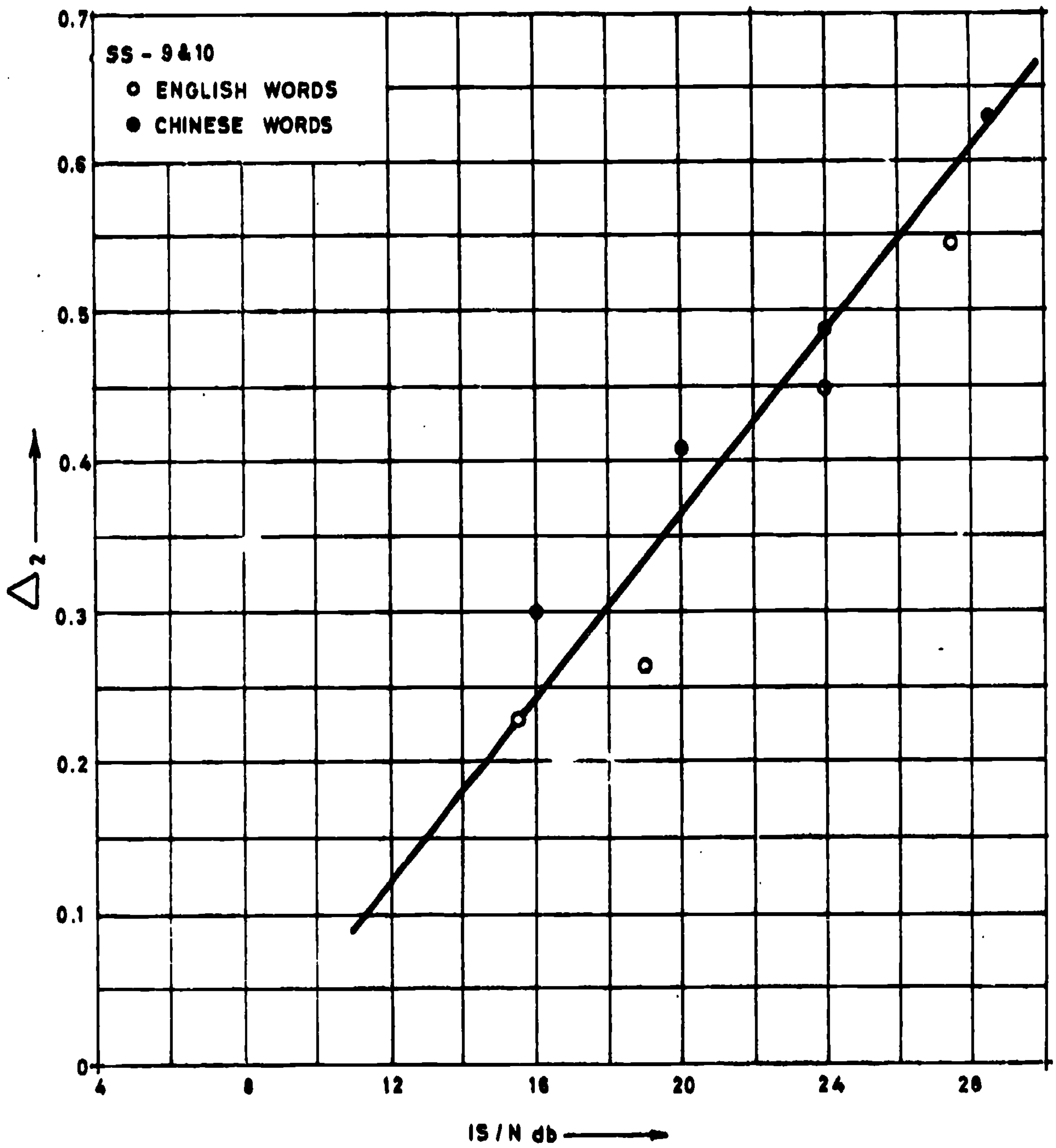


Figure 17

From this curve the corrected values of Δ_2 are determined. Finally the percentage error E corresponding to a particular value of Δ_2 was obtained from the curve in Figure 18. Values for a particular set of classrooms (SS-9 & 10) are shown in Table 4 & 5.

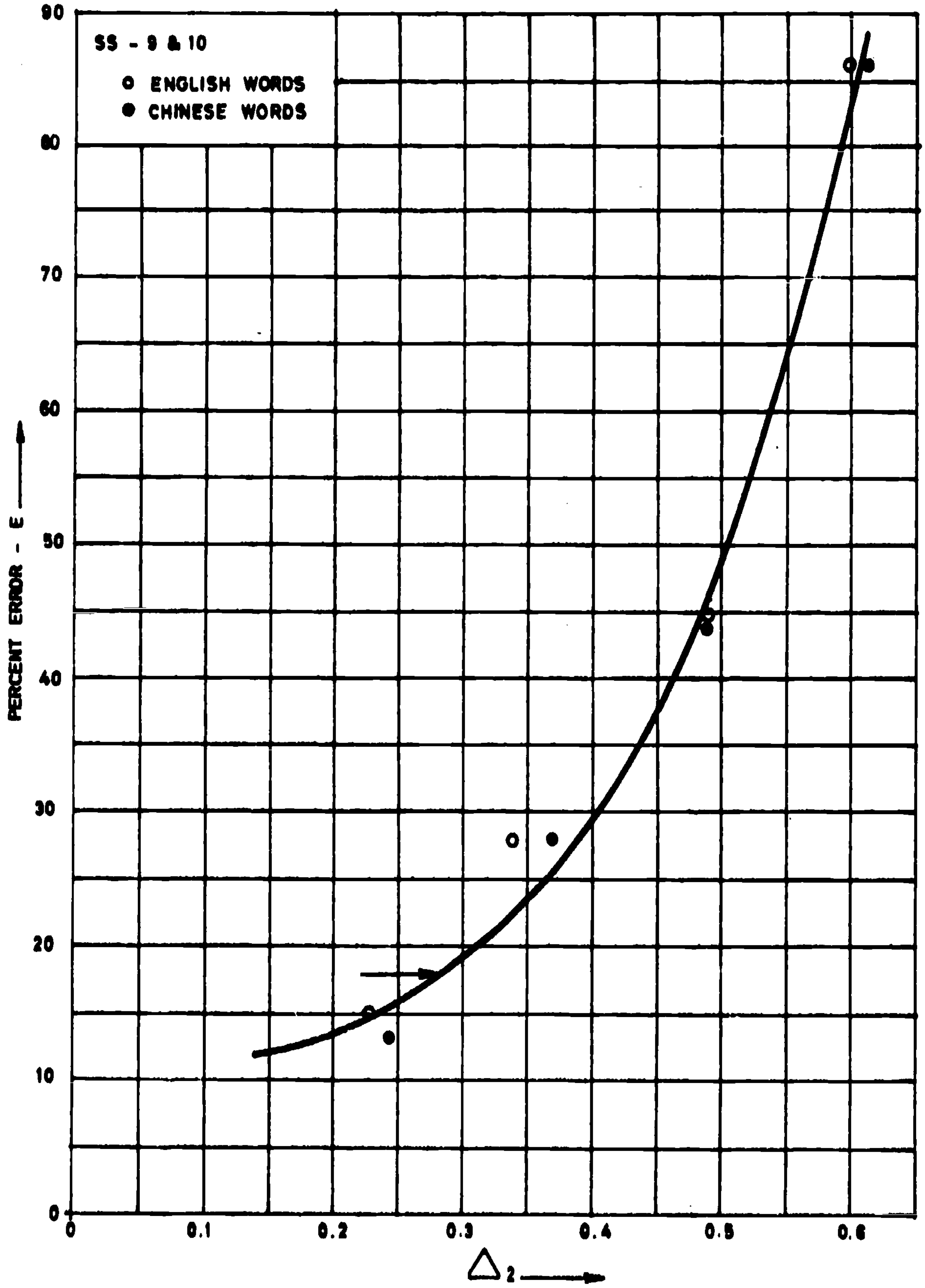


Figure 18

Table 4. Derivation of intruding speech for the schools S.S.9 and 10
B.N.L. = 52, 50 db and S.L. = 73.0 db

I.S.	Add 6 db I.S. peak	Loudness Phon I.S. peak	Mean I.S. peak	S.L. +6 db peak	Loudness Phon S.L. peak	Mean S.L. peak	IS/N (4) - (1)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
61.0	67.0	68.0	67.5				15.5
66.0	72.0	69.5	71.0				19.0
60.0	66.0	66.0	66.0				16.0
66.0	72.0	69.5	70.0				20.0
				73.0	73.0	73.0	
70.0	76.0	75.5	76.0				24.0
70.0	76.0	72.5	74.0				24.0
74.0	80.0	79.0	79.5				27.5
74.0	80.0	77.5	78.5				28.5

Table 5. Percentage error for different values of Δ_2 for schools S.S.9 and 10

IS/N	Calculated Δ_2	Corrected Δ_2	Percent error E
15.5 E	0.23	0.23	14.0
16.0 CH	0.30	0.245	15.0
19.0 E	0.265	0.340	23.5
20.0 CH	0.410	0.370	26.5
24.0 E	0.450	0.490	46.0
24.0 CH	0.497	0.490	46.0
27.5 E	0.545	0.600	81.0
28.5 CH	0.630	0.630	95.0

E means English language
CH means Chinese language

Four final curves, one for each country were drawn between the corrected value of Δ_2 and percent error E. Again the data was computerised to determine the correlation curve and the correlation coefficients (γ). The equations of this curve are given beside the curves in Figures 19 to 22.

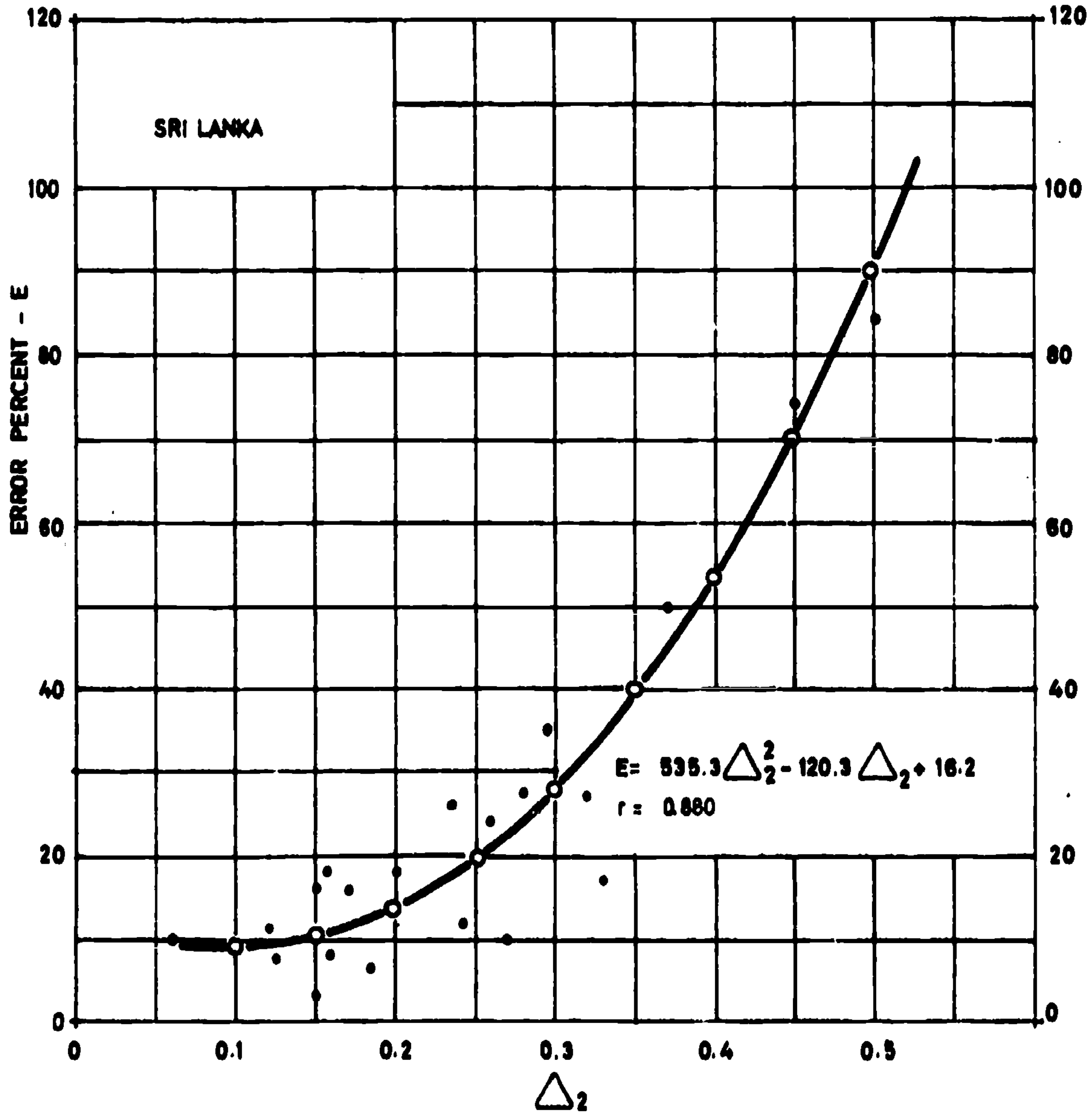


Figure 19

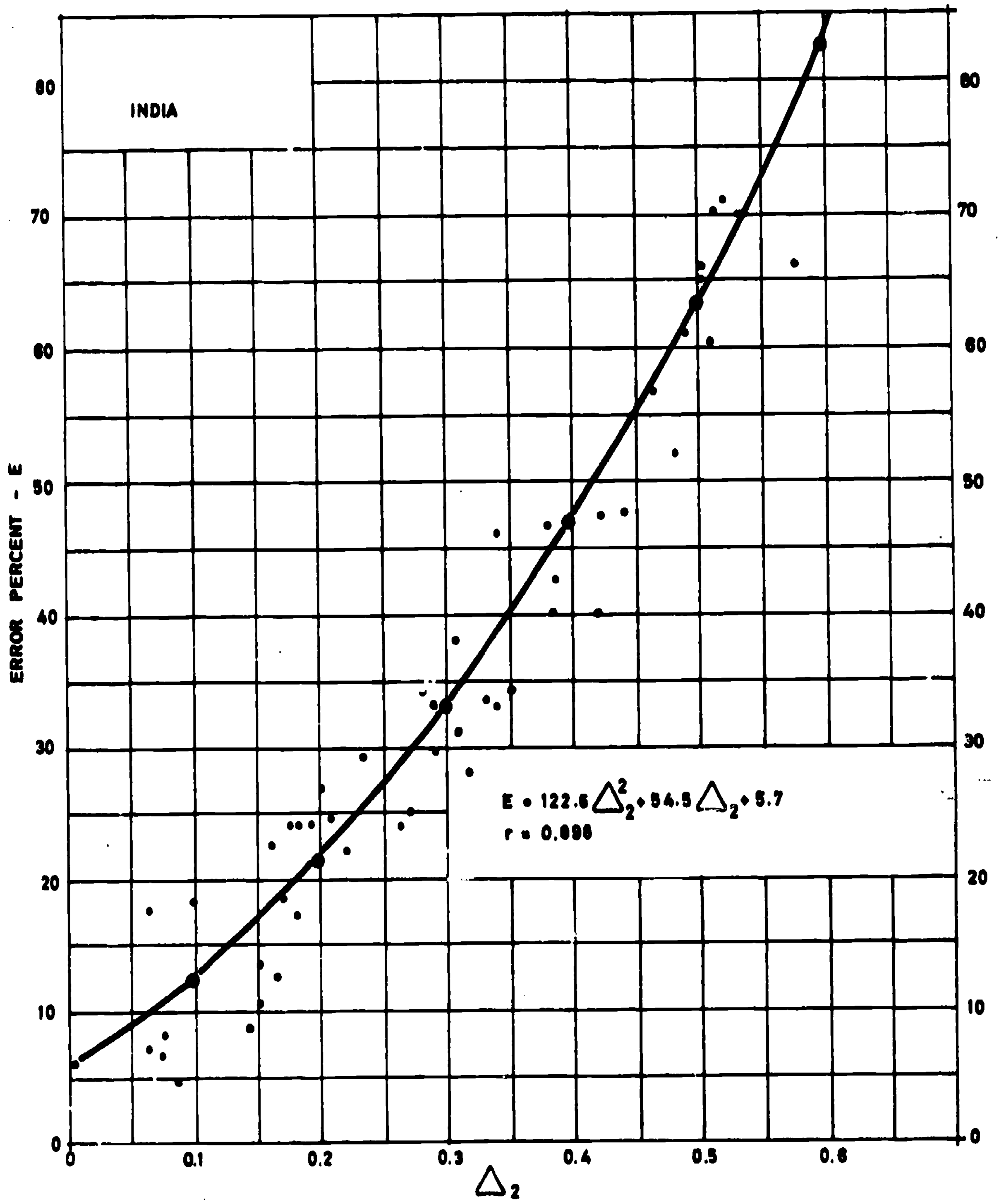
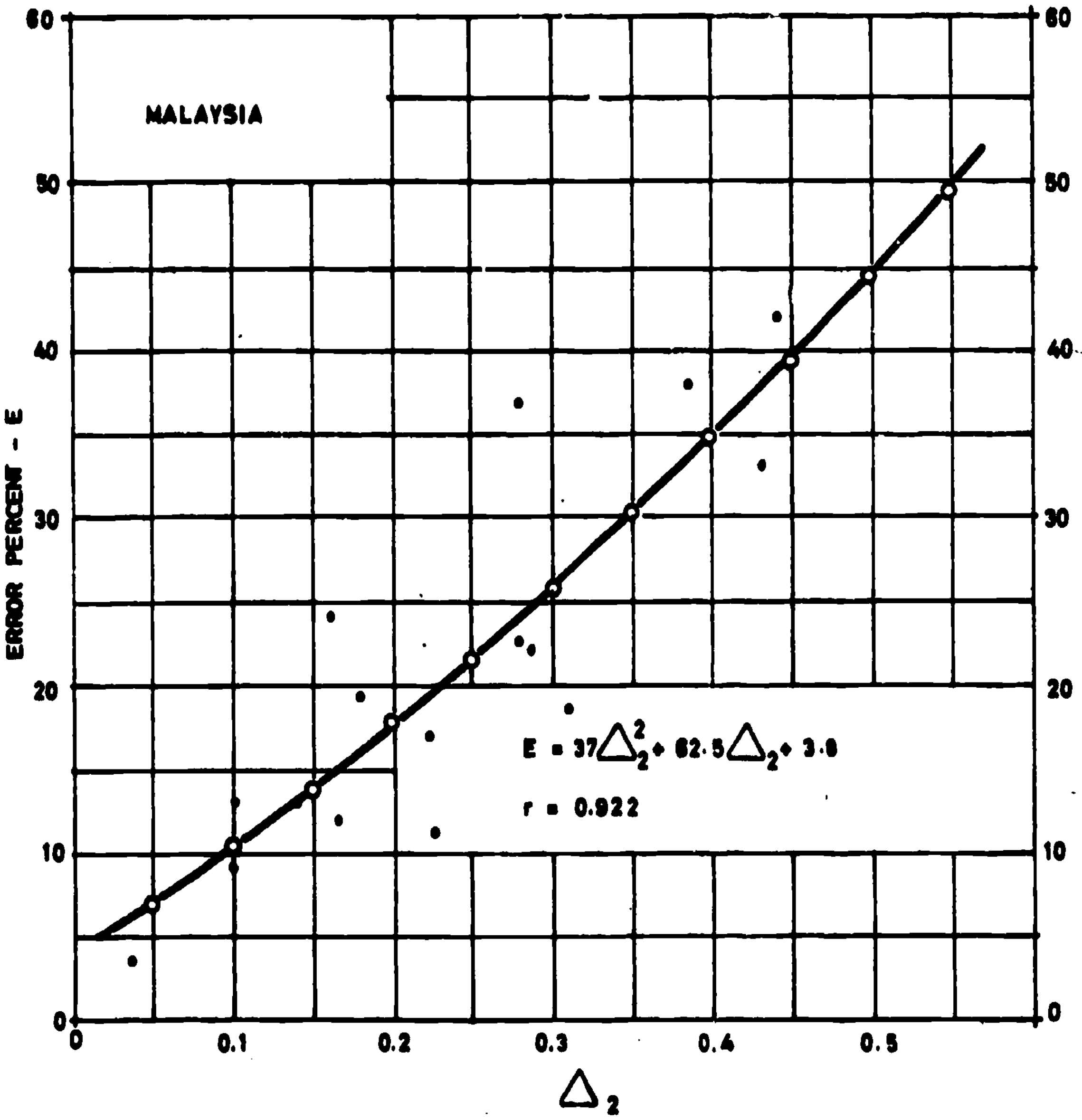

INDIA
ERROR PERCENT - E
$E = 122.6\Delta_2^2 + 54.5\Delta_2 + 5.7$
r = 0.898
Δ_2
0
10
20
30
40
50
60
70
80
0.1
0.2
0.3
0.4
0.5
0.6

Figure 20



MALAYSIA
ERROR PERCENT - E
$E = 37\Delta_2^2 + 62.5\Delta_2 + 3.8$
r = 0.922
0
10
20
30
40
50
60
0
0.1
0.2
0.3
0.4
0.5
Δ_2

Figure 21

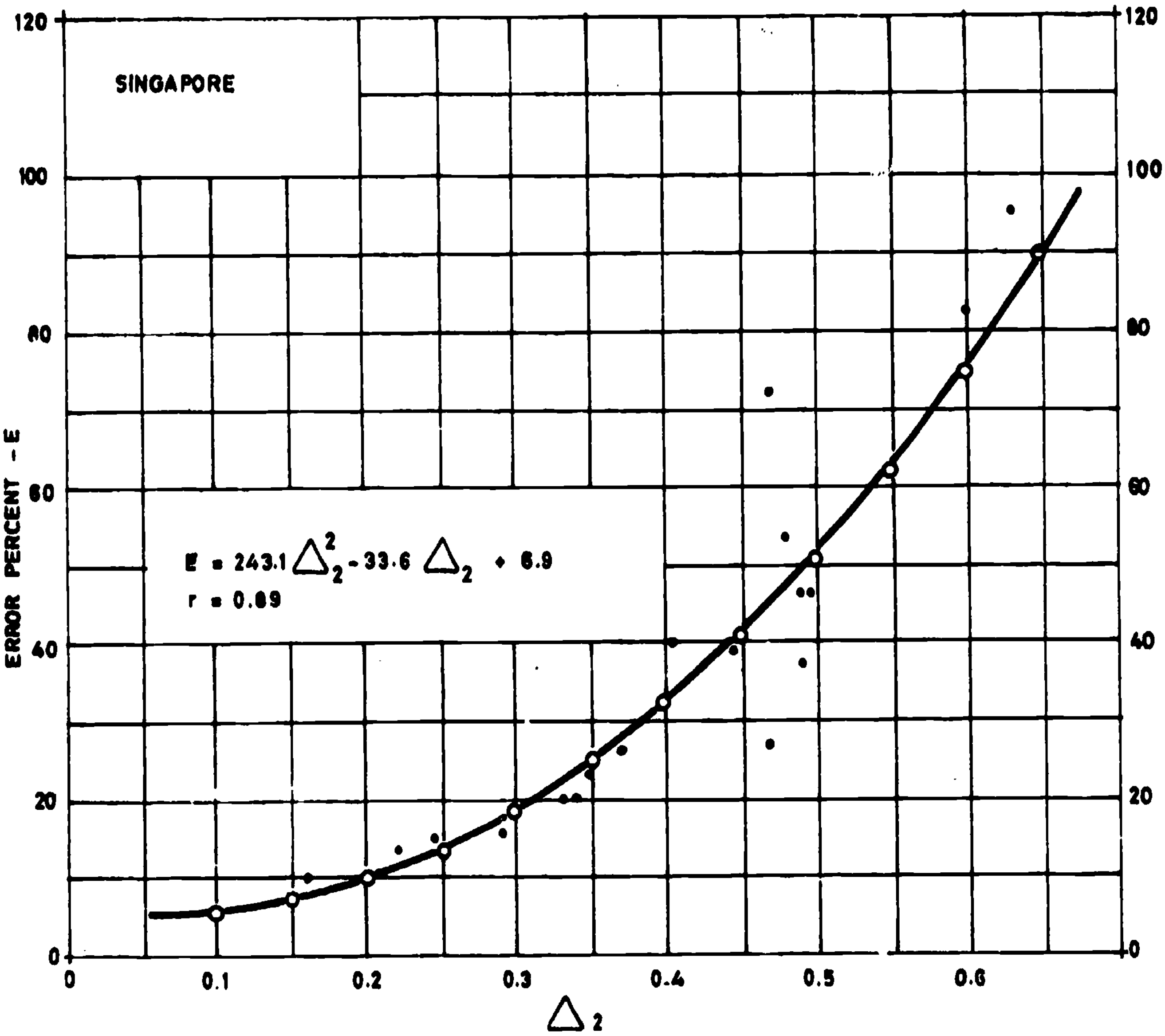


Figure 22

The correlation coefficients in all the cases are very high and of the order of 0.8 to 0.9., thus showing a definite relationship exists between $\triangle_2$ and percentage error E.

Table 6. Derivation of percentile

School	Percentage of students making errors below 15 % for	
	Δ_1	Δ_2
CG - 1 & 2	83.3	83.3
CC - 5 & 6	100.0	85.7
CC - 7 & 8	85.7	85.7
CH - 9 & 10	93.3	87.5
CD -11 & 12	83.0	85.8
CD -13 & 14	83.0	35.5
CC -15 & 16	83.0	79.0
CC -17 & 18	75.0	62.5
IG - 1 & 2	43.75	25.0
IG - 3 & 4	66.7	50.0
IG - 5 & 6	80.0	-
IG - 7 & 8	90.0	20.0
IG - 9 & 10	40.0	-
IK - 1 & 2	93.3	44.4
IK - 3 & 4	66.7	20.0
IK - 5 & 6	60.0	50.0
IR - 3 & 4	40.0	85.7
IR - 5 & 6	60.0	77.8
IR - 7 & 8	80.0	90.0
MP - 1, 2 & 3	25.1	75.0
MK - 4 & 5	100.0	71.4
MK - 6 & 7	100.0	80.0
MJ -10 & 11	50.0	50.0
MK -12 & 13	94.0	90.0
MS -14 & 15	40.0	66.6
SS - 1 & 2	91.7	87.5
SS - 3 & 4	100.0	57.0
SS - 5 & 6	87.5	85.7
SS - 7 & 8	81.25	87.5
SS - 9 & 10	100.0	82.0
SS -11 & 12	92.0	75.0
SS -13 & 14	100.0	72.0

It is observed from Table 6 that under normal conditions about 80 - 100% students make mistakes not exceeding 15%. Thus we consider the values of Δ_1 and Δ_2 corresponding to the 15% error as normal and acceptable values. Such values for a 15% error can be determined from the final curves of Δ_1 vs E and Δ_2 vs E. The values for different countries are given in Table 7 to 10. The mean values are given in Table 11.

These tables also show the values of S/N and IS/N for different countries. The results of calculation of mean and median values of S/N and IS/N corresponding to the accepted values of Δ_1 and Δ_2 are given in the Table 7 to 10.

Table 7. Derivation of the mean values of S/N and S/I.S. for Sri Lanka

School	S/N at $\Delta 1$ = 0.200 or 15% error	Values at $\Delta 2$ = 0.205 or 15% error	
		IS/N	S/N
CG - 1 & 2	16.0	13.8	19.0
CC - 3 & 4	-	-	-
CC - 5 & 6	15.0	13.4	19.5
CC - 7 & 8	13.4	14.0	18.5
CH - 9 & 10	14.0	14.6	18.5
CD - 11 & 12	14.6	14.8	22.0
CD - 13 & 14	12.4	15.8	18.0
CD - 15 & 16	13.0	14.2	17.0
CC - 17 & 18	15.6	15.2	20.0
Mean	14.25	14.5	19.1
Median	14.30	14.4	18.75
Mean value of S/I.S. = 4.6			

Table 8. Derivation of the mean values of S/N and S/I.S. for India

School	S/N at $\Delta 1 = 0.187$ or 15 % error	Values at $\Delta 2 = 0.125$ or 15 % error	
		IS/N	S/N
IG - 1 & 2	10.3	12.6	17.0
IG - 3 & 4	15.1	12.0	16.0
IG - 5 & 6	15.8	10.4	17.0
IG - 7 & 8	8.6	11.0	14.5
IG - 9 & 10	12.0	9.2	15.0
IK - 1 & 2	9.0	10.0	15.5
IK - 3 & 4	13.4	14.5	18.0
IK - 5 & 6	12.2	-	-
IR - 1 & 2	11.4	-	-
IR - 3 & 4	11.4	9.6	15.0
IR - 5 & 6	11.5	10.0	15.0
IR - 7 & 8	13.9	10.0	14.0
Mean Median	11.85 12.00	10.9 10.2	15.65 15.25
		Mean value of S/IS	= 4.75

Table 9. Derivation of the mean values of S/N and S/I.S. for Malaysia

School	S/N at $\Delta 1 = 0.205$ or 15 % error	Values at $\Delta 2 = 0.170$ or 15 % error	
		IS/N	S/N
MK - 1, 2 & 3	15.5	13.0	15.0
MK - 4 & 5	14.0	15.2	19.5
MK - 6 & 7	14.2	12.0	20.5
MJ -10 & 11	16.0	13.6	12.0
MK -12 & 13	12.5	13.6	19.5
MK -14 & 15	11.2	13.6	24.5
Mean Median	14.0 14.0	13.3 13.3	18.5 19.5
		Mean value of S/IS	= 5.2

Table 10. Derivation of the mean values of S/I.S. and S/N for Singapore

School	S/N at $\Delta 1 = 0.140$ or 15 % error	Values at $\Delta 2 = 0.250$ or 15 % error	
		IS/N	S/N
S.S. - 1 & 2	9.8	13.6	14.0
S.S. - 3 & 4; 3' & 4'	9.8	12.8	14.1
S.S. - 5 & 6	9.8	11.6	20.0
S.S. - 7 & 8	10.8	16.6	20.0
S.S. - 9 & 10; 9' & 10'	10.4	16.2	22.0
S.S. -11 & 12;11' & 12'	10.0	16.2	21.5
S.S. -13 & 14;13' & 14'	10.2	17.2	18.5
Mean	10.1	14.9	18.5
Median	10.0	16.2	20.0
Mean value of S/IS = 3.6			

Errors not exceeding 15 % are normally made by the students when teachers in two adjoining classrooms are positioned near the common partition. In this case the minimum height of the partition was two metres. When the teachers are positioned on the opposite ends of the adjoining classrooms and away from the common partition, more children were found to make mistakes exceeding 15 %. The percentage of the children making errors below 15 % for this case may be found by plotting a curve between Δ_2 and the percentage of students making errors not exceeding 15 %. This curve is shown in Figure 23. The increase in error is evidently due to more sound interference from

Table 11. Summary of mean values

Country	Δ_1	S/N db	Δ_2	IS/N db
India	0.187	11.85	0.125	10.9
Malaysia	0.205	14.00	0.170	13.3
Singapore	0.140	10.10	0.250	14.9
Ceylon	0.200	14.25	0.205	14.5

the intruding teacher. In order to reduce the interference and restore a condition equivalent to the earlier case (i.e. when the teachers are near the partition

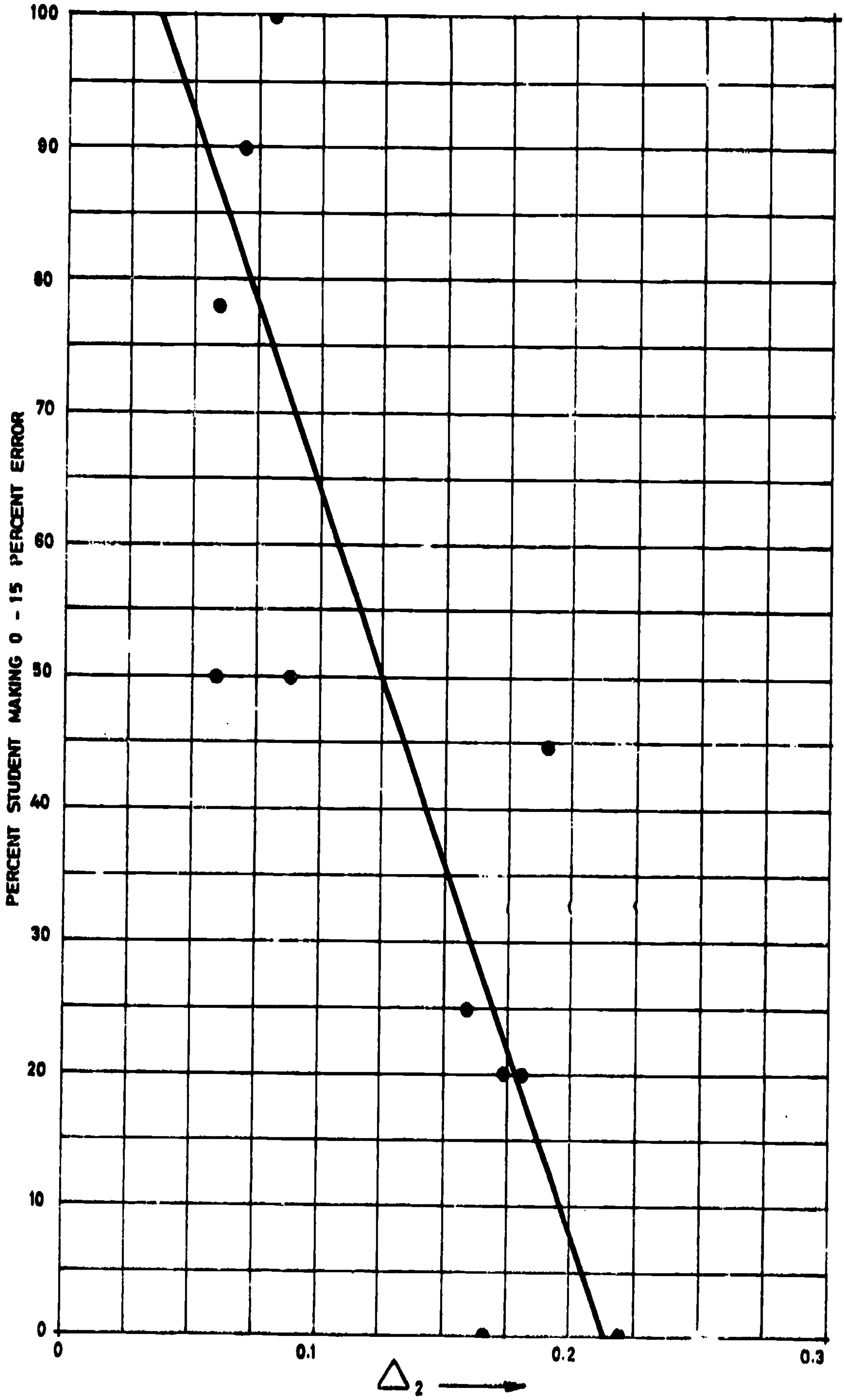


Figure 23

of two metres height), we have no other option but to raise the height of the partition to 2.4 metres. It is seen from Figures 5-10 that for a partition 2.4 metres high, there is an advantage of 2 db in Noise Reduction (N.R.) all over the seating area. This increase in N.R. would compensate the disadvantage of teacher being at opposite ends of the classrooms and away from the partition. In another test on partitions, the height was raised to 2.7 metres with a resultant advantage in noise reduction of 4 db. The partitions were tested in a room with a sloping ceiling of 2.2 metres high at the lowest point.

The reverberation time was determined in each classroom selected for test. The values of the reverberation time are summarised in Table 1.

The decline of sound in classrooms with different types of ceilings may be seen in Figure 24-26. In the case of a flat asbestos ceiling the fall of sound level with distance is quite high. This may be due to high absorption provided by the ceiling. It is observed from these curves that the sound level reduces by about 12 db. in a distance of about 7 metres, regardless of the type of the ceiling. As most of the countries require S/N ratio of 12 db. the classrooms should not be more than 7 metres long.

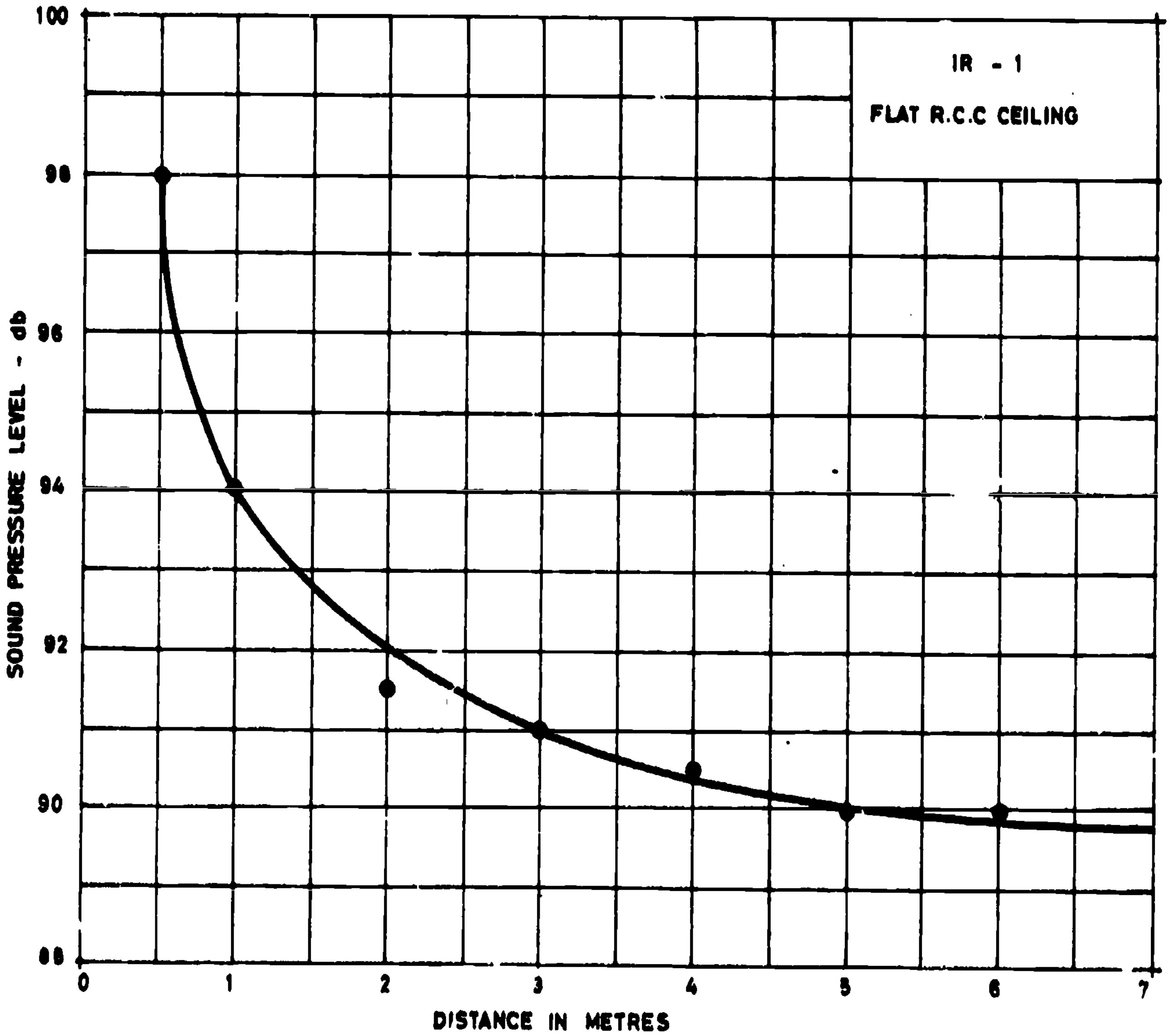


Figure 24

In the present survey, dictation was given in eight different languages. It will be seen from Figures 12 and 18 that language has hardly any effect on $\triangle_1$ or $\triangle_2$.

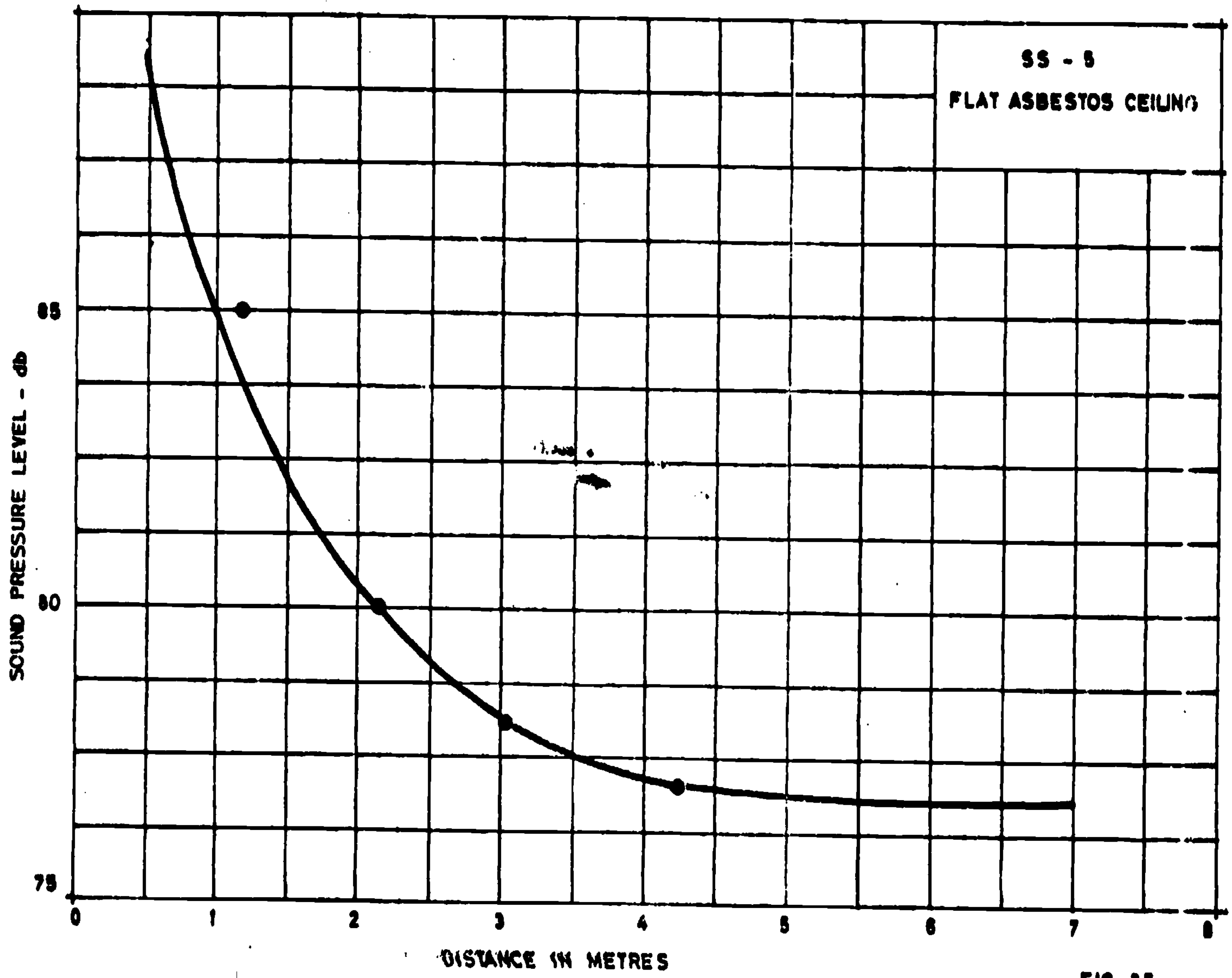


Figure 25

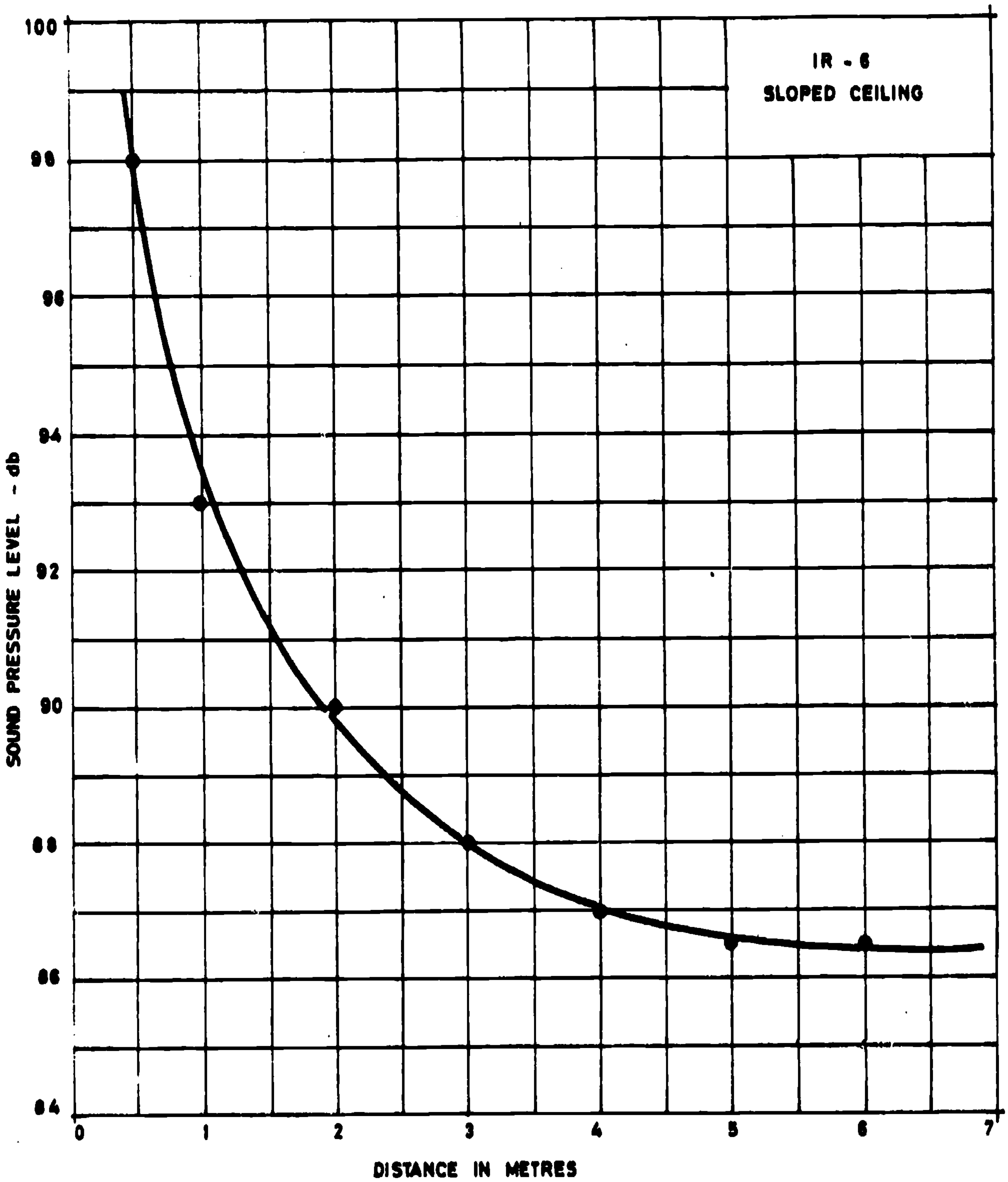

IR - 6
SLOPED CEILING
SOUND PRESSURE LEVEL - db
100
98
96
94
92
90
88
86
84
0
1
2
3
4
5
6
7
DISTANCE IN METRES

Figure 26

8. CONCLUSIONS

1. The background noise level in the teaching spaces must be less than 60 db.

2. The values of $\triangle_1$ should not be allowed to fall below 0.2 for Sri Lanka schools, 0.19 for Indian schools, 0.2 for Malaysian schools and 0.14 for Singapore schools. The corresponding values of S/N ratio are 14 db, 12 db, 14 db and 10 db, respectively (see Tables 7 to 11).

3. The values of $\triangle_2$ should not exceed 0.2 for Sri Lanka schools, 0.13 for Indian schools, 0.17 for Malaysian schools and 0.25 for Singapore schools. The corresponding difference between S/IS should be greater than 4.6 db. in Sri Lanka schools, 4.8 db. in Indian schools, 5.2 db. in Malaysian schools and 3.6 in Singapore schools (see Tables 7 to 11).

4. To achieve the required difference between direct speech and intruding speech, the partitions must be at least 2.4 metres high when the teachers are positioned at the opposite ends of adjoining classrooms away from the partition. Such flexible partitions should cover the entire width of the room. When however, the teachers are positioned back to back on either side of the same partition, the height of the partition may be reduced to 2 metres, to give at least 5 db. noise reduction which should serve the purpose.

5. No child should be more than 7 metres away from the teacher.

6. In the arrangement where teachers are positioned back to back on either side of a tall partition, the children of the two groups are automatically separated by a comfortable distance. Should the arrangement of positioning teachers at opposite ends of adjacent classrooms be chosen, there must be a "buffer zone" 2 metres wide near the partition otherwise there is a likelihood of sound interference between children of the two groups. The possible methods of creating such a buffer zone are shown in Figure 27.

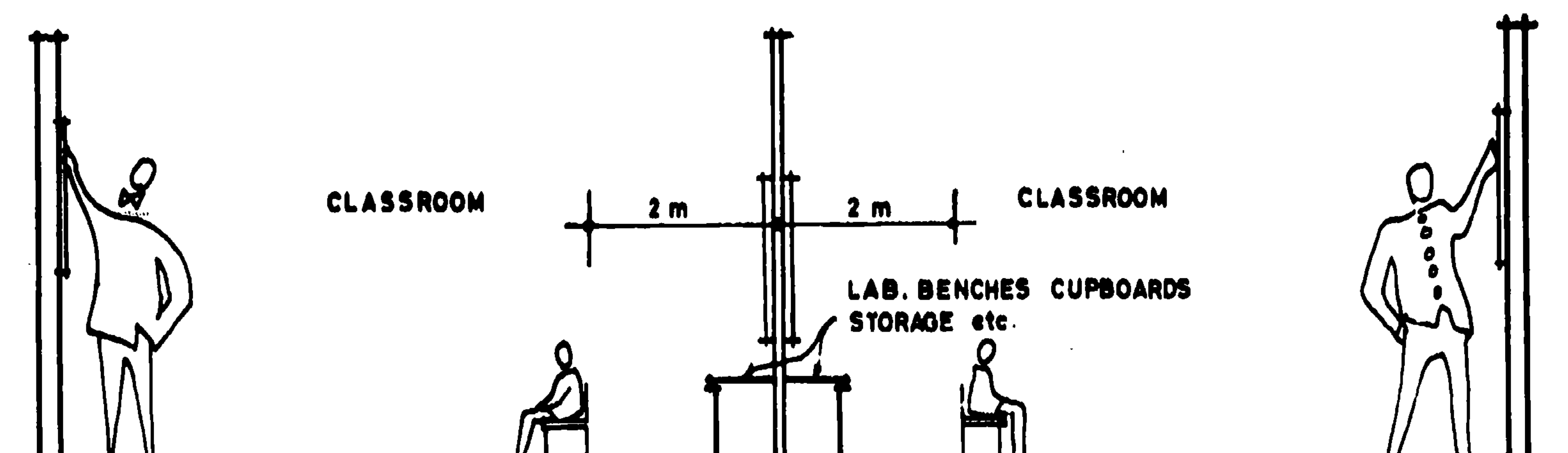


Figure 27

Test No. 1

Central Building Research Institute

ROORKEE

ACOUSTICS DATA SHEET - A

SCHOOL: IG-1 & 2 DATE: 7.9.71

STANDARD: V TAPE No: 1

ANALYSIS OF BACKGROUND NOISE AND SPEECH LEVEL
(DISTANCE OF MIKE FROM TEACHER - METRES)

Freq. Hz	Overall Background Level 58 dB LONG TIME		Background Noise Level from 58 (62)		Speech Level from 58 (62)		Δ^1 (6-4)	IF x 6000	Δ^1 x IF
	dB	Sones	dB	Sones	dB	Sones	dB		
1	2	3	4	5	6	7	8	9	10
200	41	0.93	35	0.43	48	1.80	13	2	026
250	45	1.60	35	0.67	53	2.80	18	4	072
315	44	1.70	33	0.71	50	2.50	17	6	102
400	46	1.85	35	0.84	42	1.43	07	8	056
500	46	1.85	39	1.10	47	1.90	08	10	080
630	50	2.50	40	1.20	49	2.30	09	12	108
800	50	2.50	45	1.75	52	2.70	07	14	098
1000	43	1.50	47	1.90	49	2.30	02	16	032
1250	48	2.10	42	1.43	51	2.60	09	18	162
1600	48	2.40	43	1.70	51	2.90	08	20	160
2000	46	2.50	43	1.90	50	3.20	07	22	154
2500	45	2.70	46	2.85	50	3.85	04	21	084
3150	42	2.20	42	2.20	46	2.85	04	18	072
4000	40	2.26	40	2.26	42	2.70	02	12	024
5000	37	1.83	37	1.83	32	1.36	-	-	-
		30.42	SIL	22.77		37.19			1230

CALCULATIONS:

Percentage error by students:
11.7 words

A. CALCULATION OF PHON: $S = SM + 0.15(\Sigma S - SM)$

(3) 2.70+.15 (30.42-2.70) = 2.70+4.1580 = 6.858 sones = 67.5 Ph

(5) 2.85+.15(22.77-2.85) = 2.85+2.9925 = 5.8425 sones = 65.0 Ph

(7) 3.85+.15(37.19-3.85) = 3.85+5.0010 = 8.8510 sones = 71.0 Ph

Speech/Noise ratio (7-5) = 6.0

B. CALCULATION OF SPEECH ARTICULATION INDEX (COL. 10)

$$AI = \Sigma(\Delta_1 \times IF)/6000 = 1230/6000 = 0.205$$

Central Building Research Institute

ROORKEE

ACOUSTICS DATA SHEET - B

SCHOOL : IG-1 & 2 DATE : 7.9.71

STANDARD : V TAPE No : 2

ANALYSIS OF INTRUDING SPEECH NOISE AND SPEECH LEVEL AT THE RECEIVING MIKE IN TEST ROOM

Freq. Hz	Overall Background Noise Level LONG TIME		Intruding Speech Noise Level from 64 (67)		Speech Level from 64 (67)		Δ_2 (4-2)	IF x 6000	Δ_2 x IF
	dB	Sones	dB	Sones	dB	Sones	dB		
1	2	3	4	5	6	7	8	9	10
200	41	0.93	36	0.53	40	0.87	00	2	000
250	45	1.60	40	1.00	36	0.73	00	4	000
315	44	1.70	41	1.32	38	1.00	00	6	000
400	46	1.85	48	2.10	46	1.85	02	8	016
500	46	1.85	47	1.90	45	1.75	01	10	010
630	50	2.50	51	2.60	50	2.50	01	12	012
800	50	2.50	52	2.70	51	2.60	02	14	028
1000	43	1.50	[illegible]	2.50	48	2.10	07	16	112
1250	48	2.10	[illegible]	2.50	49	2.30	02	18	036
1600	48	2.40	51	2.90	47	2.20	03	20	060
2000	46	2.50	52	3.70	52	3.70	06	22	132
2500	45	2.70	55	5.20	55	5.20	10	21	210
3150	42	2.20	55	5.20	54	4.90	13	18	234
4000	40	2.26	50	4.50	50	4.50	10	12	120
5000	37	1.83	46	3.50	43	2.75	-	-	-
		30.42		42.15		38.95			970

CALCULATIONS :

Percentage error by students : 20.0 words

A. CALCULATION OF PHON : $S = SM + 0.15\,(\Sigma S - SM)$

(3) 2.70 + .15 (30.42 - 2.70) = 2.70 + 4.1580 = 6.858 Sones = /67.5 Ph/

(5) 5.20 + .15 (42.15 - 5.20) = 5.20 + 5.5425 = 10.7425 Sones = /74.0 Ph/

(7) 5.20 + .15 (38.95 - 5.20) = 5.20 + 5.0625 = 10.2625 Sones = /73.5 Ph/

B. CALCULATION OF INTRUDING SPEECH AI (COL. 10)

$IAI = \Sigma(\Delta_2 \times IF)/6000$

$= 970/6000$

$= 0.162$

APPENDIX C

Central Building Research Institute

ROORKEE

ACOUSTICS DATA SHEET - C

SCHOOL: IG-1 & 2 DATE: 7.9.71

STANDARD: V TAPE No: 2

NOISE REDUCTION ANALYSIS

Freq. Hz	Intruding Speech Level Near the Mouth of Teacher in SR, 1 ft away from the teacher 72 dB. dB	Sones	Intruding Speech Level in Test Room 61 dB, Mike in the centre dB	Sones	Noise Reduction (2-4) dB
1	2	3	4	5	6
200	40	0.87	35	0.47	5
250	43	1.40	41	1.10	2
315	48	2.10	43	1.50	5
400	51	2.60	48	2.10	3
500	53	2.90	45	1.75	8
630	59	4.50	53	2.90	6
800	62	5.54	52	2.70	10
1000	60	4.70	50	2.50	10
1250	51	2.60	47	1.90	4
1600	53	3.40	48	2.40	5
2000	58	5.50	49	2.95	9
2500	61	8.20	52	4.30	9
3150	64	9.64	54	4.90	10
4000	58	7.90	48	4.00	10
5000	55	6.30	46	3.50	9
		68.15		38.97	

CALCULATIONS: $S = SM + 0.15\,(\Sigma S - SM)$

(3) $9.64 + .15\,(68.15 - 9.64) = 9.64 + 8.7765 = 18.4165$ Sones = [82.5 Ph]

(5) $4.90 + .15\,(38.97 - 4.90) = 4.90 + 5.1105 = 10.0155$ Sones = [73.5 Ph]

OVERALL N.R. (3-5): 82.5 - 73.5 = 9.0 PHON

DIMENSIONS OF THE CLASS ROOM

IG - 1 : 6M x 5M x 4M

IG - 2 : 7.2M x 6M x 4M

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