

DESIGN DEVELOPMENT OF OFFICE LANDSCAPE
PARTITIONS THROUGH ACOUSTICAL RESEARCH

by 6408

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CHAPTER I

INTRODUCTION

In the United States today, almost half the work force spends approximately one third of their lives working in an office. When one spends a substantial amount of the day in this type of environment, it may have a great psychological effect on him. To insure the proper environment for the specific work to be accomplished the space should be carefully designed and these psychological factors evaluated.

Although little is known of how people function in an office or what effect the environment of the office has upon the quality of work being done, the efficiency achieved, or the communication between workers, today a new concept is being applied to the design planning and operation of offices. This concept has been used in Europe and is just beginning to be used in this country. It is called office landscaping. (See Figure 1.1, Plate I) Office landscaping, as an approach to designing the office environment, embodies systems analysis, consideration of human factors and an intimate understanding of environmental control. As it has been tested and put into use in Europe, it shows signs of becoming a significant development in the planning of more comfortable yet more efficient offices. There is good reason to believe this is so, for office landscaping considers the office as a totality. It is not an application of decoration

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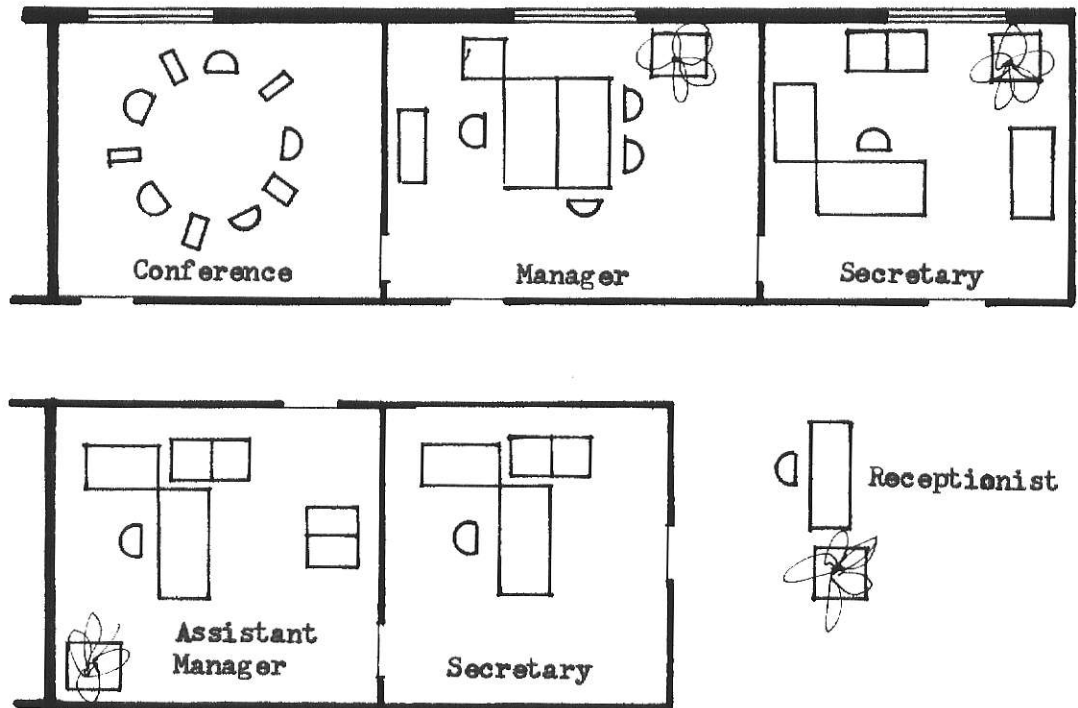


Figure 1.1

Traditional Office Plan

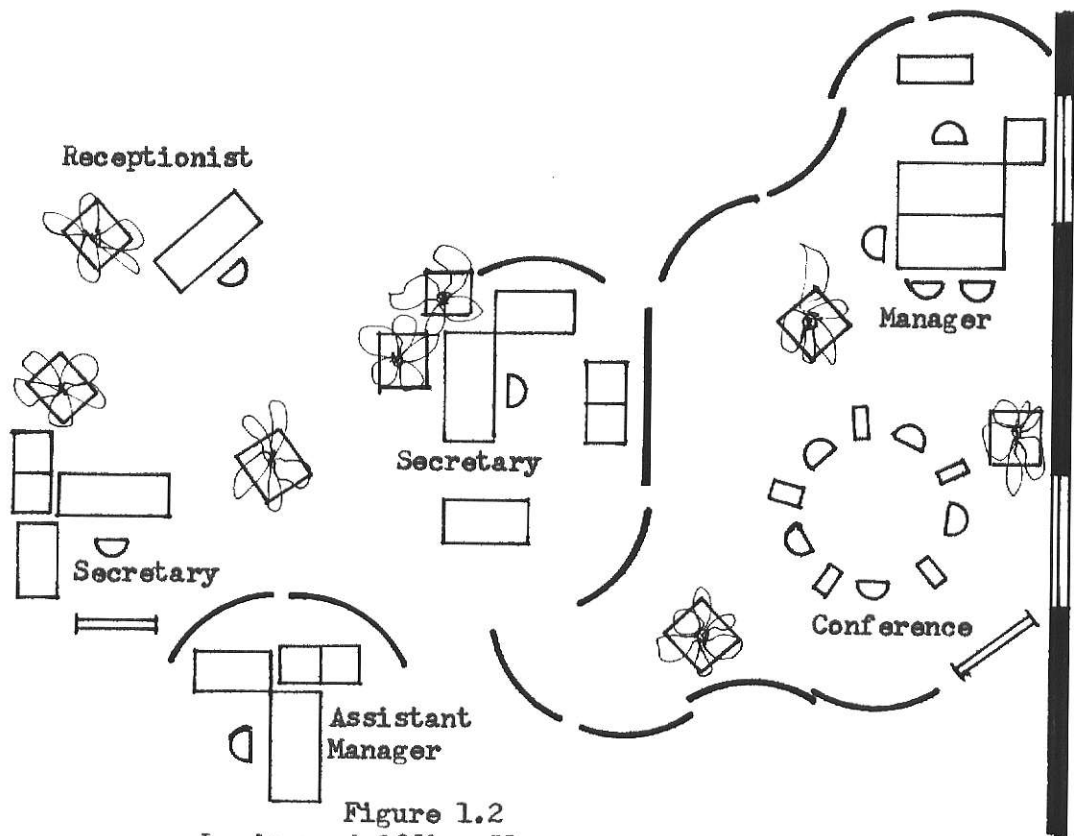


Figure 1.2
Landscaped Office Plan

Scale: $3/32" = 1'0"$

upon an architecturally predetermined space.

Office landscaping involves planning the office to eliminate all unnecessary visual barriers (walls), and through careful grouping and interrelationship to allow a worker to feel himself part of the total office rather than isolated in a small, tight, confining room apart from the overall operation.

To best understand landscaping, it is probably best to take a look at linguistics. The concept of office landscaping began in Germany in the late 1950's and spread to Sweden. "The working name which the Germans gave to this concept was 'burolandschaft.' The Swedish call it 'kontorslandskap.' These phrases translated directly into English as office landscaping. However, the linguistic subtlety to be understood is that landscaping in German and Swedish does not connote 'vista' or the view one sees as it does in English. Rather, to the Germans, landscape includes the viewer, actually precludes spectatorship and involves participation. In Swedish the involvement is carried one step further. It is a term that was once used to designate a province or prefecture; thus, an official sense of involvement in one's community."¹

The basic concept of office landscaping is to plan an environment for the particular requirement and character of organization. While

¹Office Landscaping, (The Business Press, Elmhurst, Illinois, 1969), p. 13.

there is a tendency in non-landscaped offices to provide a formula kind of sameness for every type of business organization regardless of size and character, the landscaped office design takes into account what the organization is, what tasks are involved, how they are accomplished, and what the proper tools are to do the job; in every case, the goal is to achieve higher efficiency and worker comfort.

Although the primary objective is to enable the office to function as efficiently as possible, it is equally important to remember that the staff must be made to feel comfortable and at ease: if they do not, productivity will suffer.

One of the major discomfort factors and an ever present source of distraction in the landscaped office is unwanted sound or noise. Noise may obscure or reduce the clarity or quality of communication, reduce one's ability to concentrate or it may produce other undesirable psychological effects. It results from the elimination of walls which isolate noise in the traditional office design.

All unwanted sound can be traced to two sources. These are either internal noise or external noise. The internal sources include equipment used in the office, such as office machines, ventilating systems, light fixtures, people and their varying types of conversations. The external sources include traffic noises, such as cars, buses, trucks and aircraft.

Reduction of external sources is possible through proper prior site selection of the building, making certain it is in an area zoned

for a low density of vehicular traffic and as remote as possible from heavily traveled thoroughfares. A desirable factor in selecting a building site or determining the sound insulation needs of a building is to make a noise survey to estimate the noise contributions from both present and future traffic conditions and select wall materials accordingly. Figure 1.3 Plate II shows the relationship between the average outdoor noise level (at the street curb) in decibels and the flow of street traffic in terms of vehicles per minute. Another possibility in the reduction of street noise is to locate the building at a distance as remote as possible from this source. Table I shows the necessary distances to produce noise level reduction. Roughly stated, each doubling of the distance from the source will reduce the ambient sound level by six decibels.

TABLE I
NECESSARY DISTANCES TO PRODUCE NOISE LEVEL
REDUCTION IN BUILDING LOCATIONS

Traffic	Distance (ft.)	Noise Level (db.)
Main Thoroughfare	20	75-80
Main Thoroughfare	100	60-65

Source: Otto Gottschalk, Flexible Administration Structures, Maurischat and Bevensee, Quickborn, Germany, 1968, p. 157.

PLATE II

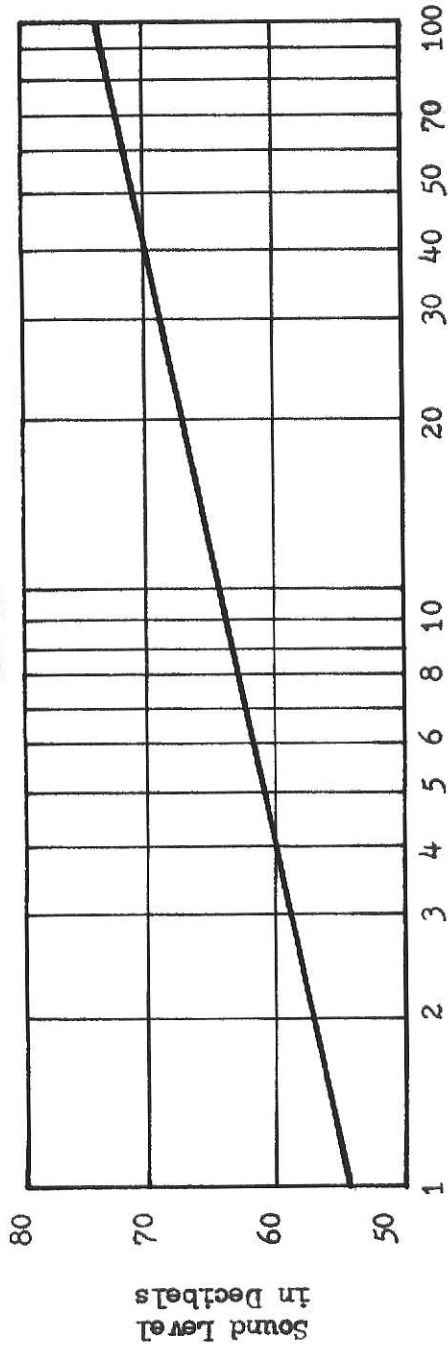


Figure 1.3
Relationship Between Outdoor Noise and the Density
of Vehicular Traffic

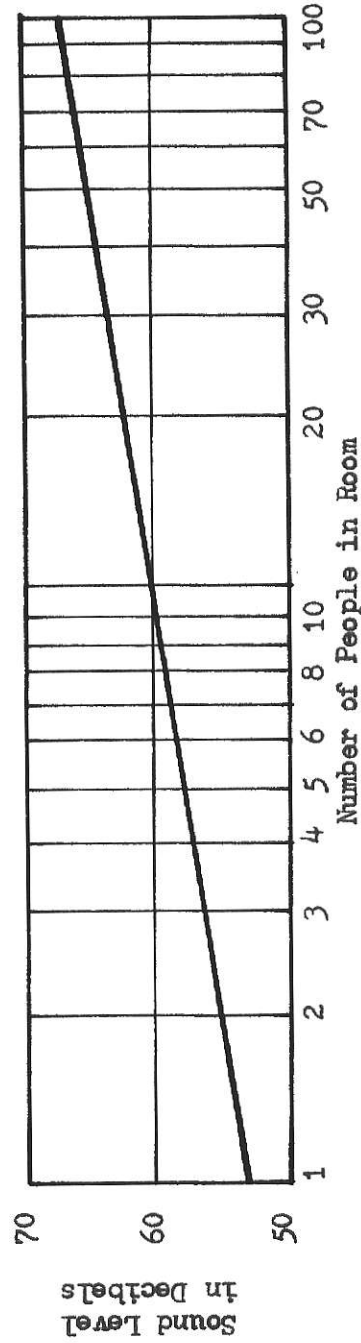


Figure 1.4
Relationship Between Room Noise at Business Locations
and the Number of People in the Room

Source: V. O. Knudsen and C. M. Harris, Acoustical Designing in Architecture
(New York) p. 214, 219.

Noise from ventilating systems is one of the major contributors to internal noise. However, if properly designed, the ventilating or air conditioning system will operate quietly enough to insure it will not contribute unduly to the background noise level of the space. The noise from the ventilating system can be reduced until it is negligible when compared to other noise in the room. This reduction of noise is achieved by: the suitable choice and installation of motors, lining of ductwork, proper sizing of fans and grilles, and streamlining of the air-transmitting system so that turbulence is eliminated.

The reduction of background noise produced by office machinery, such as typewriters, accounting, sorting, adding and data computing machines, is achieved by redesign of the machine mechanism paying particular attention to the noise generating parts. Acoustical dampening material can be used in conjunction with these machines to further dampen noise levels. As an example: metal gears and bearings can be replaced with nylon gears and bearings, and the machine vibrations can be reduced by using vibration isolating materials and dampeners. Figure 1.5 Plate III gives a graphical representation of such a corrective measure.

The last major internal source is the people. "The greater number of people in a room, the noisier it is." However, the higher the background noise level, the louder an individual must speak in order to be heard above the noise.

PLATE III

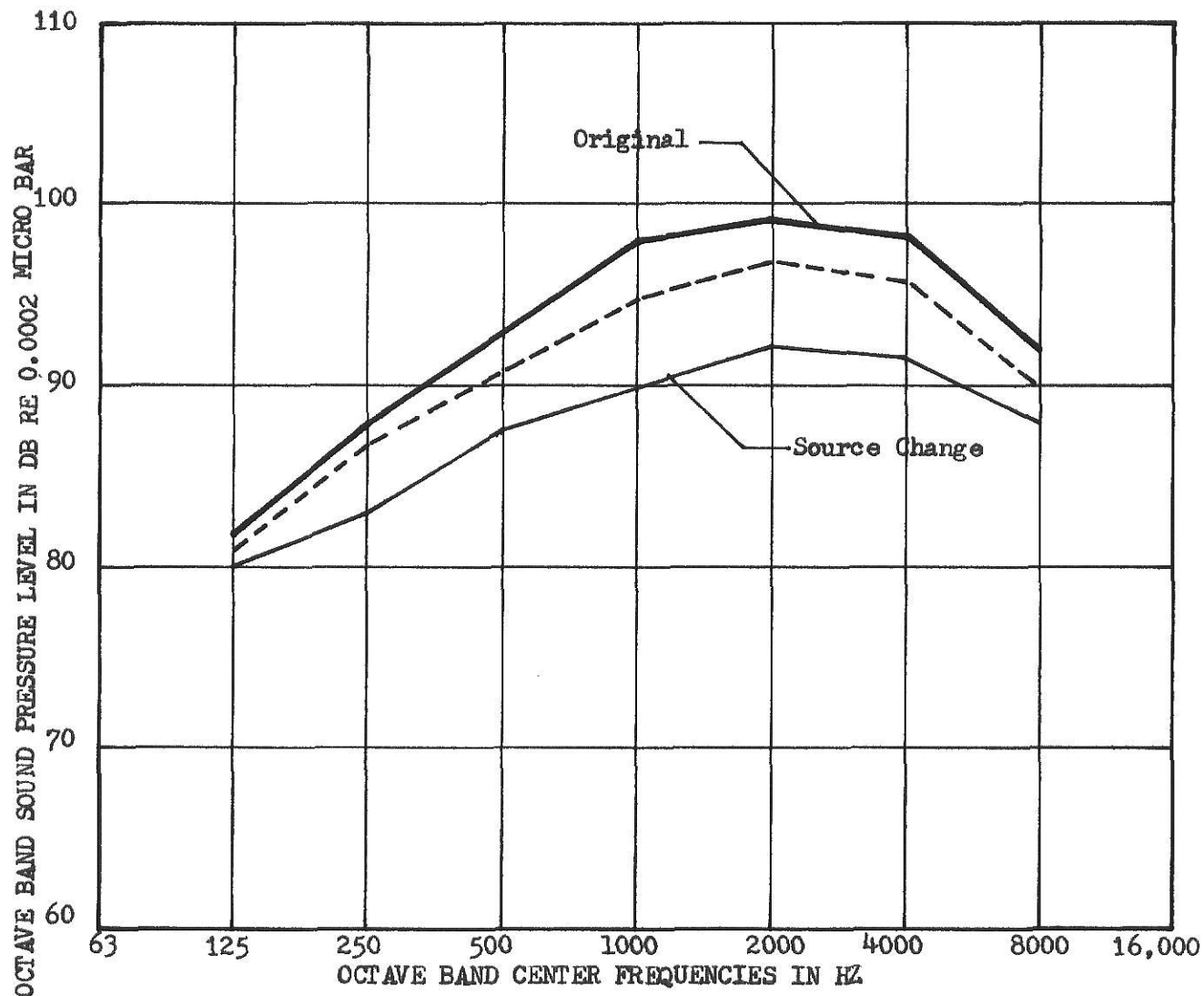


Figure 1.5

Noise Reduction Resulting from Alternative Corrective Measure

From the above it can be seen that the best solution is to quiet noise by corrective redesign at the source.

Although acoustical material has some distinct advantages, it seldom will produce the benefits to be gained by quieting the noise source directly.

From the last statement it becomes obvious that although acoustical materials applied to walls, floors and ceilings will do little to reduce the noise sources, they will help to reduce the general background sound level, reduce reverberation times and give the landscaped office a general "deadness." This suggests that the effect of acoustical materials in reducing the noise level in a room may be twofold. First, they help reduce the overall noise level and second, since the absorptive treatment tends to lower the background noise level, they allow individuals to speak more quietly and still be heard. Hence, the "people" noise level is reduced at its source. Figure 1.4 Plate II gives the approximate relationship between the noise in a business office and the number of people in the room.

Acoustical materials should not be used as "catch all" remedies for poor acoustics; however, they are useful in controlling noise levels within a room by reducing the reverberation time and by increasing the average room absorption coefficient.

In consideration of the previous statements, the first step toward achieving a total solution to the acoustical problems of the landscaped office involves:

- a. Isolating the building from external sources - using wall construction of a proper nature to accomplish the necessary insulation from outside noise levels.
- b. Eliminating all internal equipment noise from typewriters, ventilation fans, adding machines, and similar equipment.

- c. Reducing the need for loud conversation through a general deadening of the space, using sound absorbing materials on all walls, floors and ceilings.
- d. Reducing the reverberation time as low as is possible, through maximal absorption.

When these alterations have been accomplished, the sources of prime contribution to the overall noise level of the space will have been reduced as much as is possible. An office space thus designed would then approach the theoretical "free field" condition.

An office which has been analyzed and corrected as mentioned in (a) through (d) above will have an optional background noise level of 50-55 db. The important noise problem in such an office will now become not the elimination of background noise but the elimination of the occasional intermittent interruptions caused by talking and the use of office machines.

To resolve the balance of this landscaped office noise problem, it is therefore necessary to find ways to acoustically isolate people in a theoretical "free field." The "free field" is represented in Figure 1.6 Plate IV as an open space, outdoors free from any interfering objects as wall or ceiling boundaries. The direct sound from a source to a receiver is the only sound considered; all other sound dissipates into the air. On the other hand, a typical indoor office (Figure 1.8 Plate IV) has many reflecting surfaces resulting in a higher sound level and a longer reverberation time. Using highly absorbent acoustical materials for wall, floor and ceiling surfaces,

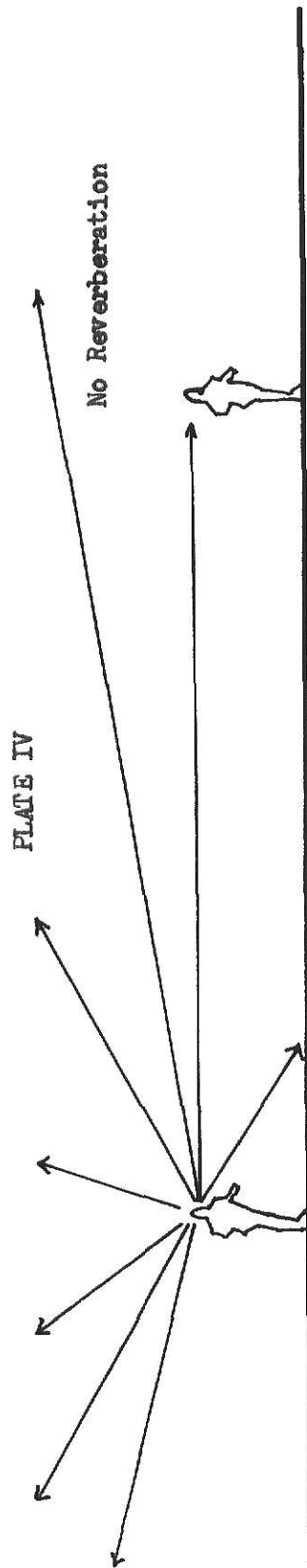


Figure 1.6

Free Field Condition (out-of-doors)

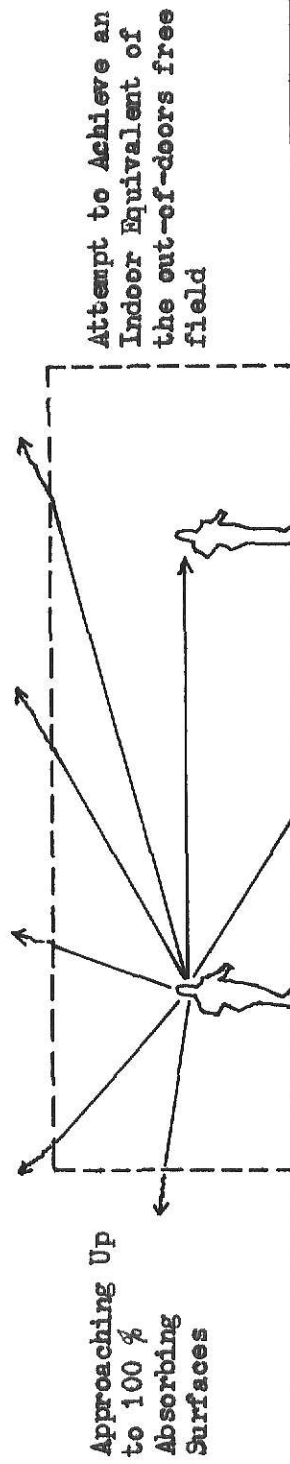


Figure 1.7

Synthetic Free Field Condition

Theoretical Goal of Office Landscaping

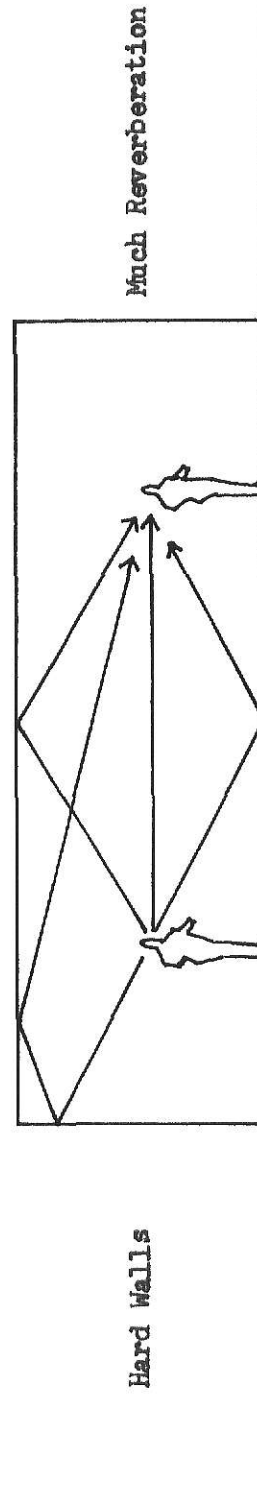


Figure 1.8

Reverberant Field Condition (indoors)

we can approach the theoretical "free field" and thus reduce the overall reverberation time, reduce the sound level and therefore, approximate what can be termed a "synthetic free field." (Figure 1.7 Plate IV) Under such conditions the only remaining major acoustic concern is how do we reduce or eliminate the annoyance from the effect of the direct sound energy.

As can be seen from Table II, typically encountered sounds would be clearly heard above the 50-55 db. background noise level and would be classified as disturbing intermittent sounds.

TABLE II
NOISE LEVELS OF VARIOUS SOURCES MEASURED
AT VARIOUS DISTANCES FROM THE SOURCE

Sources	Distance (ft.)	Noise level (db.)
Press	3	80
Telephone Ring	7	75
Sorting Machine	3	75
Door Closing	10	72
Typewriter	7	68
Adding Machine	13	67
Talking	3	65

Source: Otto Gottschalk, Flexible Administration Structures, Maurischat and Bevensee, Quickborn, Germany, 1968, p. 158.

Although office landscaping involves isolating workers from undue distraction of various office machines, this is not the only problem.

Work spaces in large offices lacking floor to ceiling walls for acoustical isolation have to be arranged in such a way that conversation cannot be overheard. The articulation limit in relation to distance alone from the source in a free field is shown in Table III below.

TABLE III
LIMIT OF SPEECH ARTICULATION WITH
RESPECT TO VARIOUS TYPES OF SPEECH WITH
A GIVEN BACKGROUND NOISE LEVEL

Function	Speech Noise at 3.5 (ft.) Distance	Noise Level	Speech Articulation Limit (ft.)
Dictation			
Telephone	60-65	52-55	13-17
Conversation			
Dictation	65-75	45	34-40

As can be seen from Table III, it is possible to understand speech as typically encountered in an office at distances of as far as 17 feet from the source.

Source: Otto Gottschalk, Flexible Administration Structures, Maurischat and Bevensee, Quickborn, Germany 1968, p. 160.

Under these conditions, speech privacy does not exist in large landscaped office spaces, because the economical desk spacing is less

than the maximum limit for articulation. To solve this problem partitions must be used to reduce the sound levels.

In summation, it is the intent of this thesis to determine the criteria for the design of partial partitions or screens and other surfaces which might be used to achieve acoustical privacy while not limiting or defeating the overall intent of the concept of office landscaping when used in a "synthetic free field" indoors, and by determining how sound flows in such spaces and how sound moves around barriers as typically encountered in office spaces.

CHAPTER II

PROBLEM FRAMEWORK

Acoustics is the science of sound, its production, transmission and effects. To understand the research conducted, a basic knowledge of terms used is required.

Office noise, being a major part of this research, can be defined as unwanted sound that may obscure or reduce the clarity or quality of communication, reduce one's ability to concentrate or produce other undesirable psychological effects. From a physical evaluation, sound is a disturbance of the air, which results in a change in air pressure level measured by the decibel (db.). Sound meters measure pressure levels using either A, B, or C weighting networks or scales. When on the C - scale, the meter registers essentially a flat or equal response to all sounds over the full range of 20-20 K Hertz (Hz.). The B - weighting network was not used. The A - scale discriminates against lower frequencies, and some high frequencies, as does the human ear at moderate sound levels, thus permitting measurements which closely approximate "loudness" as the subjective term related to human hearing.

"Frequency" is the number of times per second that the sound pressure alternates above and below the ambient atmospheric pressure. Each complete alternation is called a cycle, and frequency is expressed in cycles per second (cps.) or Hertz (Hz.). A "phon" is a unit to measure the loudness level of a pure 1,000 Hz. tone which is judged by

the ear to be of equal loudness. The "threshold of audibility" is the minimum sound pressure level of a specific signal that is capable of causing an auditory sensation.

Terms used to describe the characteristics of sound waves as they travel through the air are shown on Plates V, VI, and VII.

"Diffraction" is the ability of a sound wave to flow around obstacles and/or through openings with little energy loss. "Diffusion" is the scattering or dispersion of sound within a space so that a uniform density of energy exists throughout. "Attenuation" is the reduction of the intensity of a sound signal. "Absorption" is the reduction of sound energy whereby the wave motions is entrapped and dissipated in the form of heat. "Reflection" is the ability of a surface to redirect a sound wave front. Under normal conditions the angle of incidence is equal to the angle of reflection. "Masking" is the process by which the threshold of audibility for one sound is raised due to the presence of another (masking) sound.

PLATE V

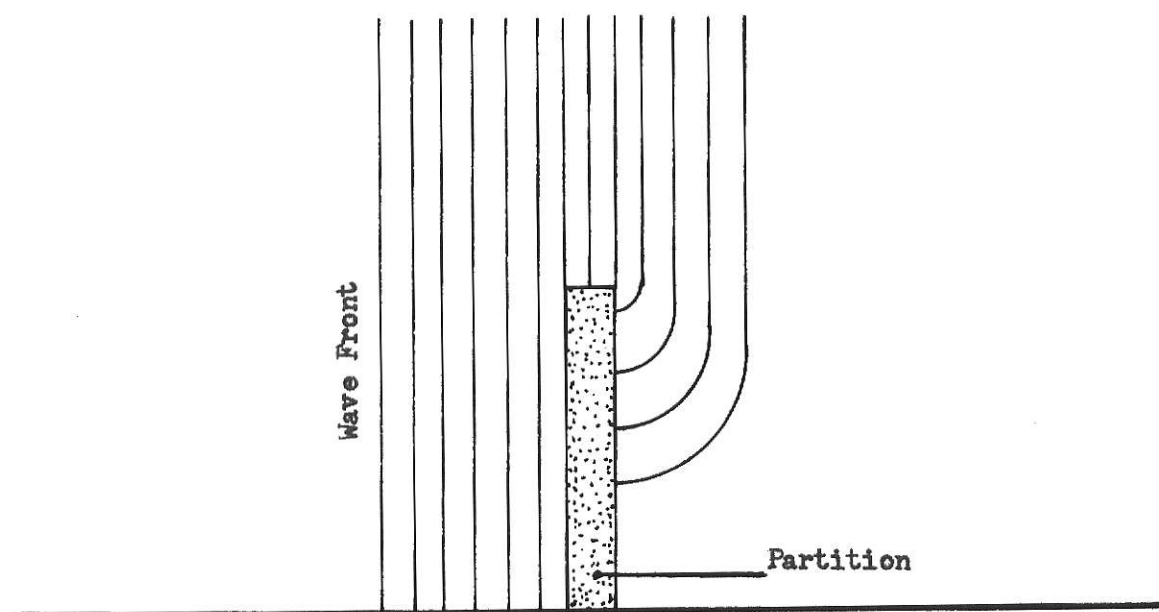


Figure 2.1

DIFFRACTION OF PLANE WAVES AT THE EDGE OF
A PARTITION

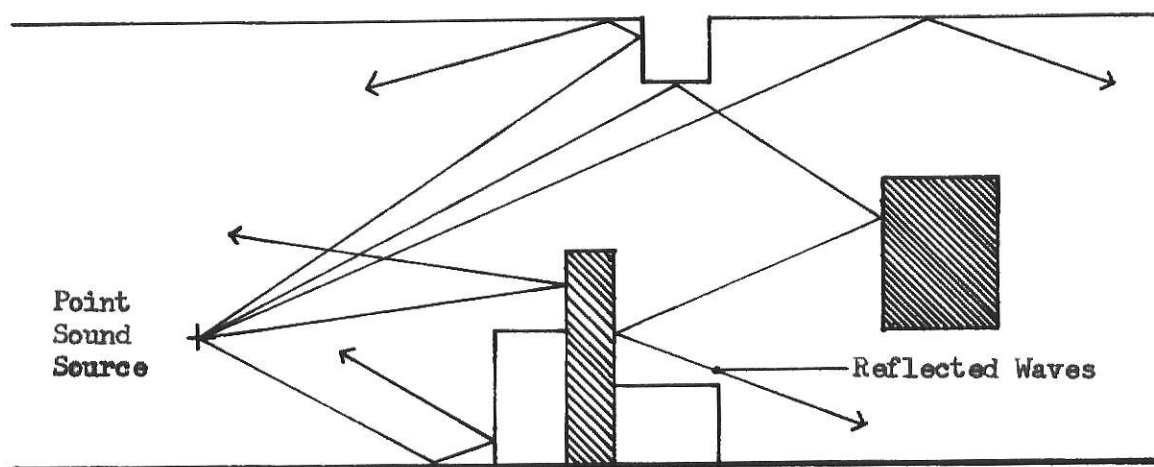


Figure 2.2

DIFFUSION OF A POINT SOUND SOURCE
IN A ROOM WITH MANY SMALL
IRREGULAR OBJECTS

PLATE VI

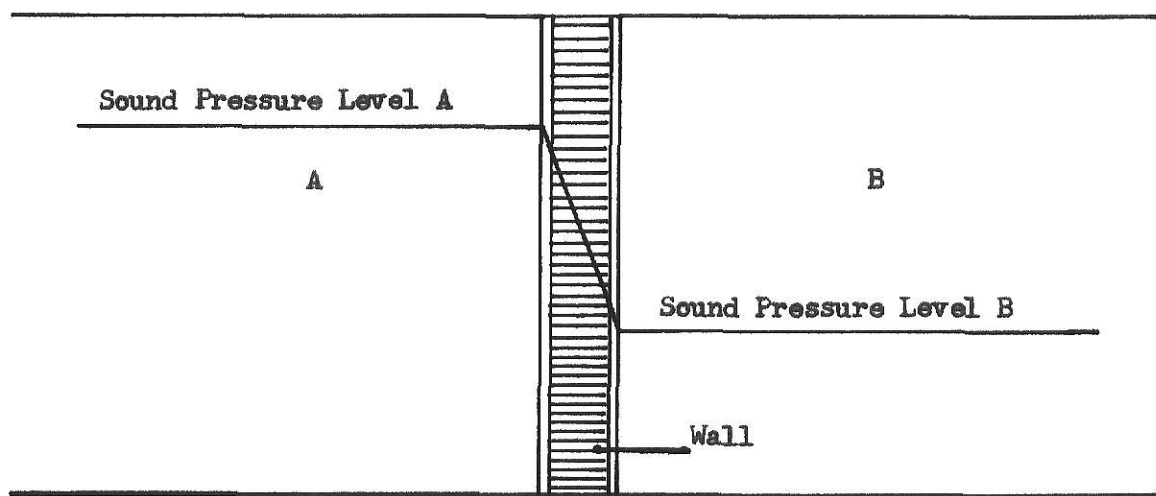


Figure 2.3

ATTENUATION OF SOUND PRESSURE LEVEL FROM
ROOM 'A' TO ROOM 'B' BY WALL

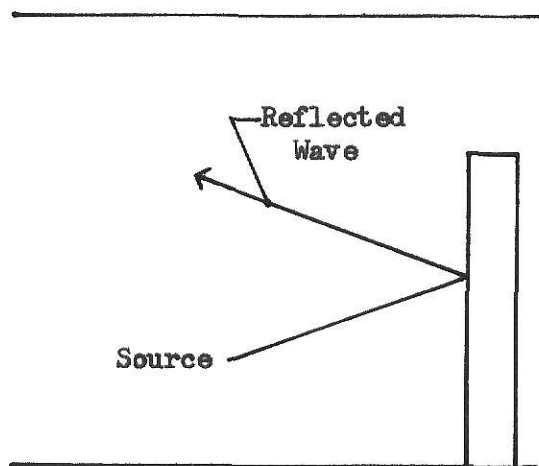


Figure 2.4

Sound from Source Reflected by
Wall

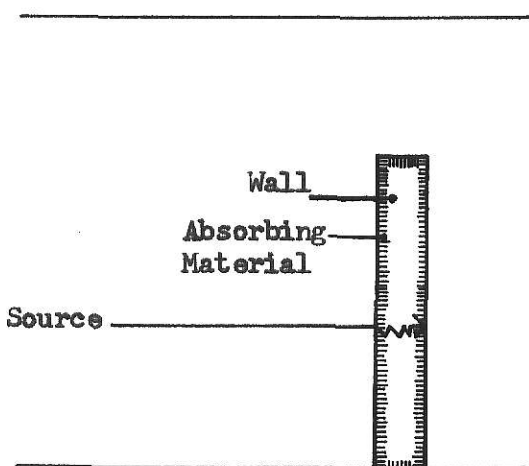


Figure 2.5

Sound from Source Absorbed by
Wall Filled with Absorbing
Material

PLATE VII

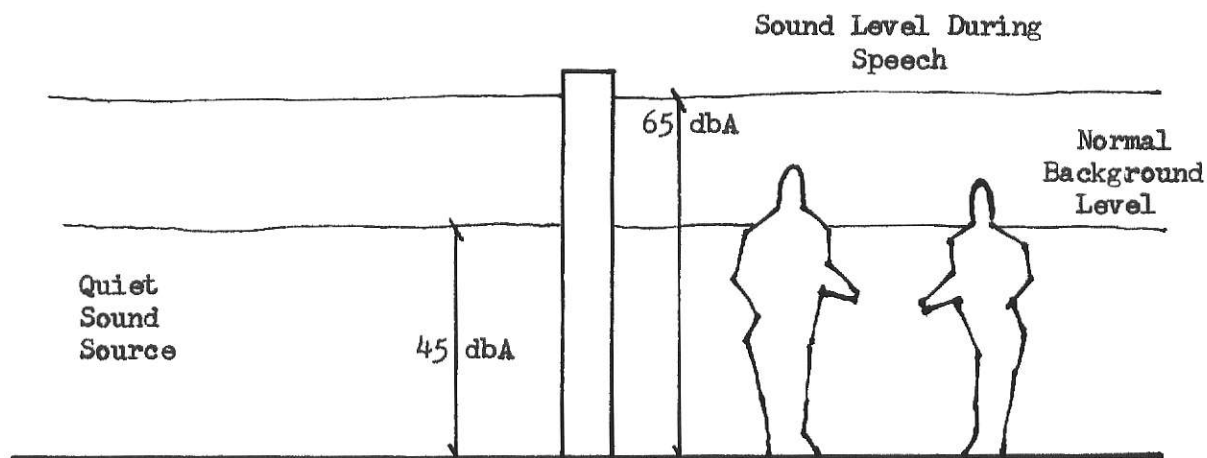


Figure 2.6

THE SOUND SOURCE OF THE BACKGROUND LEVEL IS BELOW THE SOUND LEVEL DURING SPEECH, WHICH ALLOWS SPEECH TO BE HEARD.

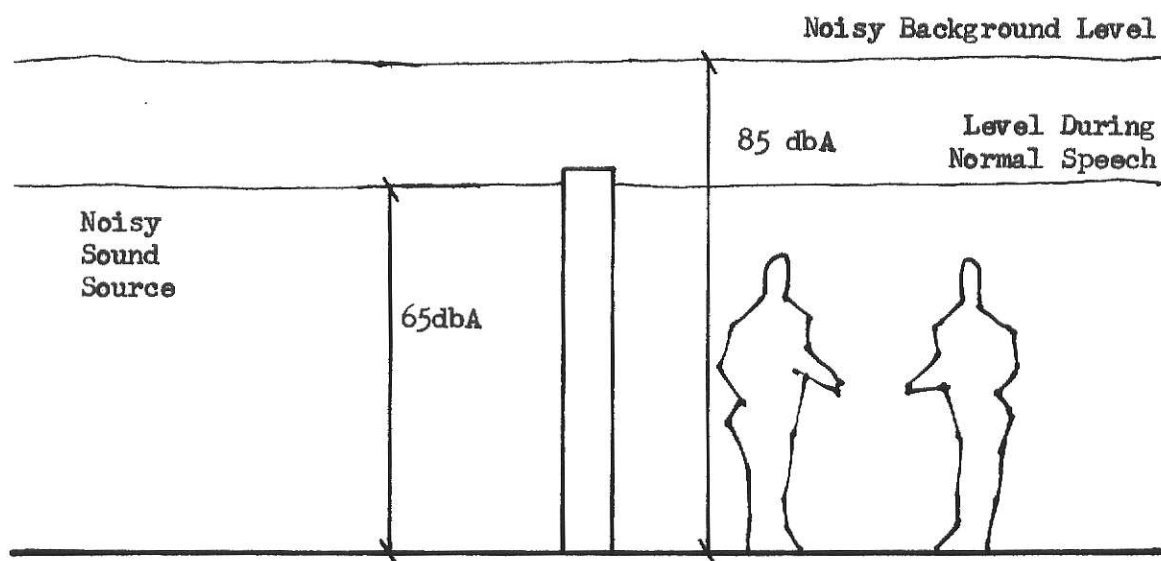


Figure 2.7

THE NOISY BACKGROUND LEVEL IS HIGHER THAN THE SPEECH LEVEL AND THEREFORE 'MASKS' THE SPEECH

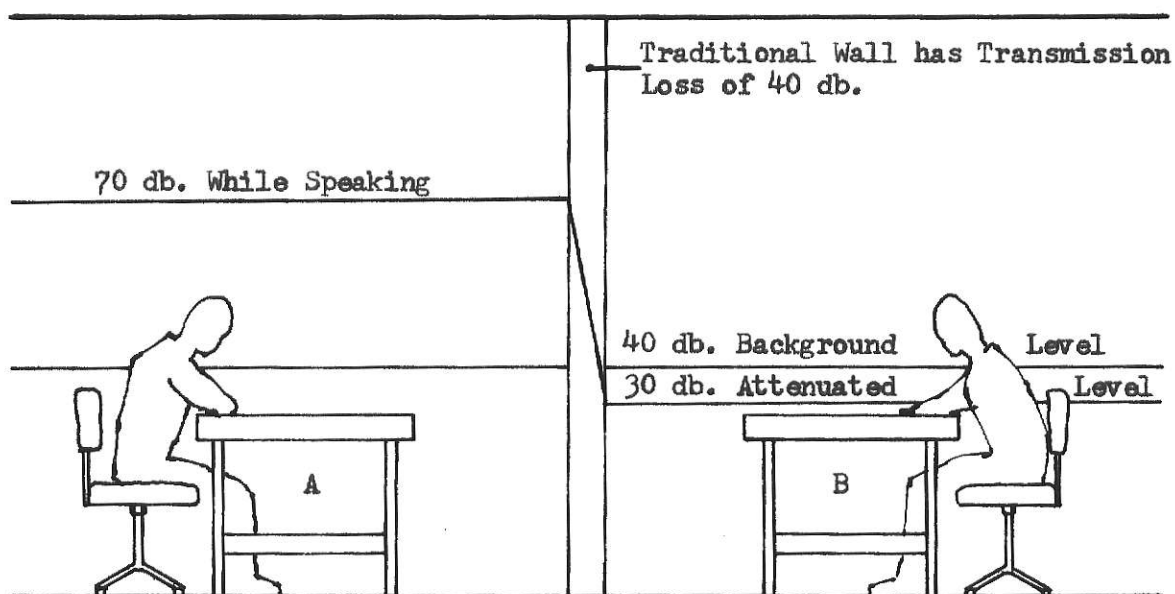
This thesis concentrates on noise, one of the environmental elements that affects the comfort of the office worker in a landscaped office. Noise is a major distraction in any working space; however, this is particularly true in the landscaped office.

While the general treatment applied to the wall, floor and ceiling of a typical landscaped office materially reduces the overall sound level and significantly reduces reverberation, it does not reduce the energy of the direct sound waves from a source to the ear. In fact, this general quieting actually makes the clarity of direct sound more obvious, and speech can be heard over great distances. Because of this, the privacy found in a typical walled-in office does not exist in the landscaped office. Figure 2.8 Plate VII explains why.

In the traditional office the flow of sound energy from A to B is controlled by the transmission quality of the wall separating the two. The path is primarily a solid born path and by proper design, 40 db. of attenuation can readily be achieved. (See Figure 2.8 Plate IX) In a landscaped office lacking walls to achieve acoustical isolation, the only way to achieve the necessary 40 db. loss (required for speech privacy) from worker A to worker B would be to separate the two workers by sufficient distance involving only an airborne path. However, air alone is not an efficient absorber. (See Figure 2.9 Plate IX)

Obviously this is not economical and space consideration would demand a close desk spacing. The problem then becomes how to reduce the direct and reflected speech signal using partial screens or

PLATE VIII



DECIBEL LOSS OF TRADITIONAL OFFICE WALL

Sound level of 70 db. resulting from worker 'A' speaking is reduced to below 30 db. by a traditional office wall having a 40 db. loss.

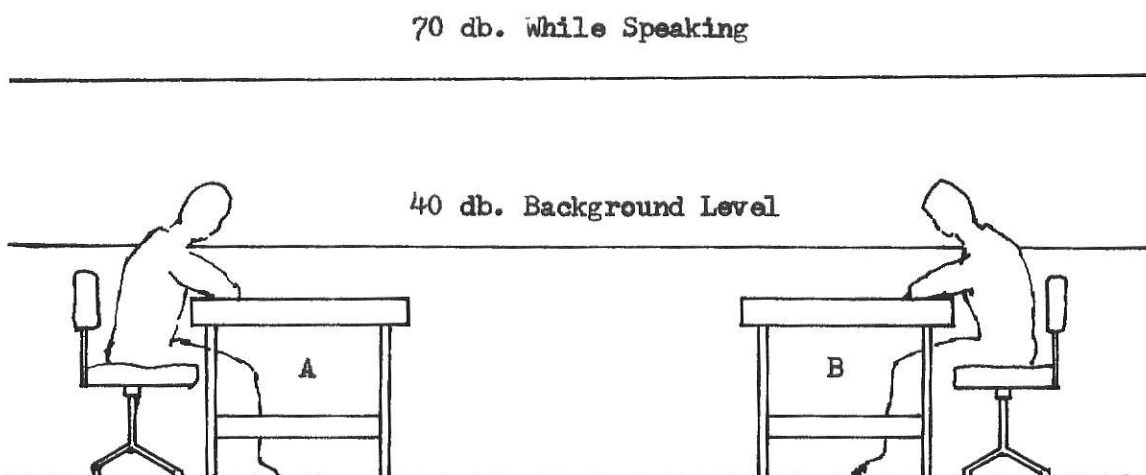
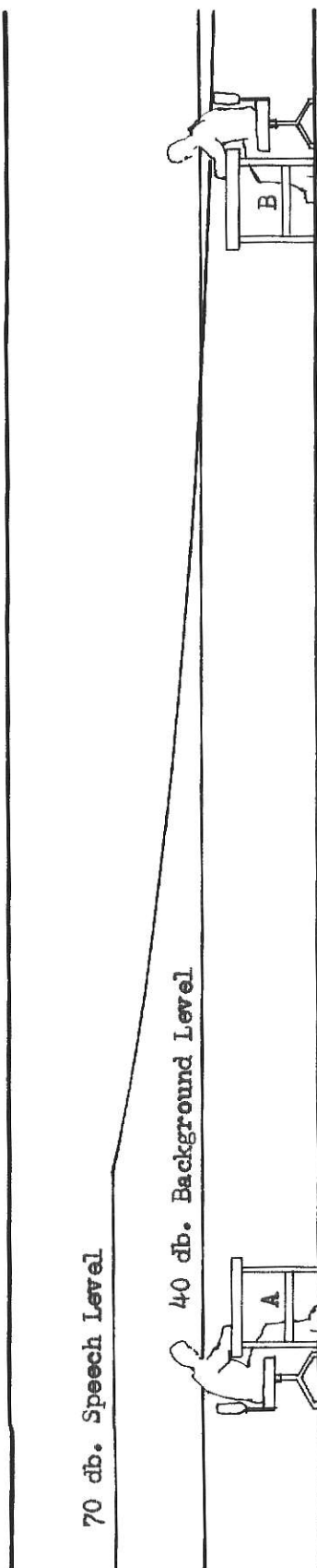


Figure 2.8

CORRESPONDING SOUND LEVEL IN A LANDSCAPED OFFICE

Sound level of 70 db. resulting from worker 'A' speaking is clearly heard by worker 'B'. No wall exists to attenuate sound.

Scale: $3/8" = 1'0"$



ATTENUATION OF SOUND WITHOUT WALLS

Without the use of walls, attenuation of a 70 db. speech source from worker 'A' to 'B' would require a great distance before the source would drop below the background level.

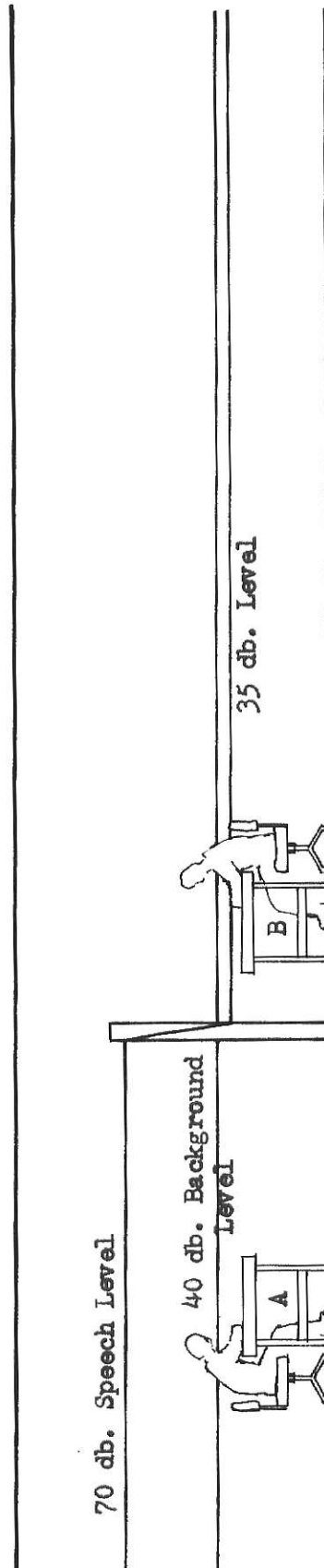


Figure 2.9

ATTENUATION OF SOUND BY USE OF SCREENS OR PARTIAL PARTITION

The 70 db. sound source is attenuated from worker 'A' to 'B' with the use of a partial partition or screen below the background level.

Scale: $3/16" = 1'0"$

dividers to attenuate the sound, while allowing an airborne path to exist.

Documented proof already exists to establish that if flanking leaks or a path of one percent or greater exists, the controlling factor becomes the flanking path.

By reducing a partition height and creating an opening between the ceiling and the top of such a screen, sound flow now becomes controlled by the flanking path and becomes a function of both reflection and diffraction involving the open space above the partitions and its resultant airborne path.

The tests carried on and hereinafter described were undertaken to permit the study of wave motion travel around barriers involving both the principles of reflection and diffraction utilizing airborne paths bounded by highly absorbent surfaces.

The partitions used to accomplish this task must prevent the bending sound wave as well as the reflected waves from reaching the opposite side of the partition.

Therefore, the research involves the development of a landscaped office partition that will control both the diffracting and reflecting sound waves from a point source as well as the reflecting of other waves in the area.

The extent of the development will be to determine theoretical shapes of partitions that in a further study can be built and tested in actual landscaped office conditions.

CHAPTER III

INVESTIGATION PHASE

In order to determine proper criteria for the designing of acoustical shapes of a landscaped office partitions and dividers, it was necessary to first determine characteristics of wave motions and how sound waves travel in a typical landscaped space. The following tests were conducted.

1. Observations of Wave Systems in a Ripple Tank.

The diffraction and reflection wave patterns, generated by a point source, are studied as they come in contact with various shapes of partitions or dividers as in a landscaped office.

2. Test of Sound Flow Around Simple Landscaped Partitions

Relating the theoretical findings of Test I, a simple barrier of material was tested in a large open space, that had acoustical treatment on the ceiling and floor, to simulate a landscaped office. A point source generated sound waves, the patterns of which were plotted as they reacted to the partial partition.

3. Existing Planning Office

An existing furnished office divided into spaces by fixed, connected partitions was used to investigate

sound pressure level contours the effects resulting from a point source on partial partitions, partial partition with an acoustical ceiling, and a carpeted floor, and full partitions with acoustical ceiling and carpeted floor.

4. Observations of Speech Articulation

Criteria for speech audibility was investigated in a large open central space of a bank. The personal observations of the three members of the investigation team were recorded as well as those of employees working in the space.

These reports follow:

Test I

OBSERVATIONS OF WAVE SYSTEMS IN A RIPPLE TANK

Purpose

Cross sections of a typically proportioned room with and without partial dividers and with varying absorption qualities were constructed in a ripple tank. (See Figure 3.1 Plate X) This was done to establish how wave motions of mid-range and low frequency move and diffract around openings above these dividers and how waves are reflected from various shaped and acoustically treated surfaces.

Technique and Equipment

A ripple tank with a glass bottom filled with $\frac{1}{4}$ inch of water was used to permit the projection of wave motions upon a screen. By means

PLATE X

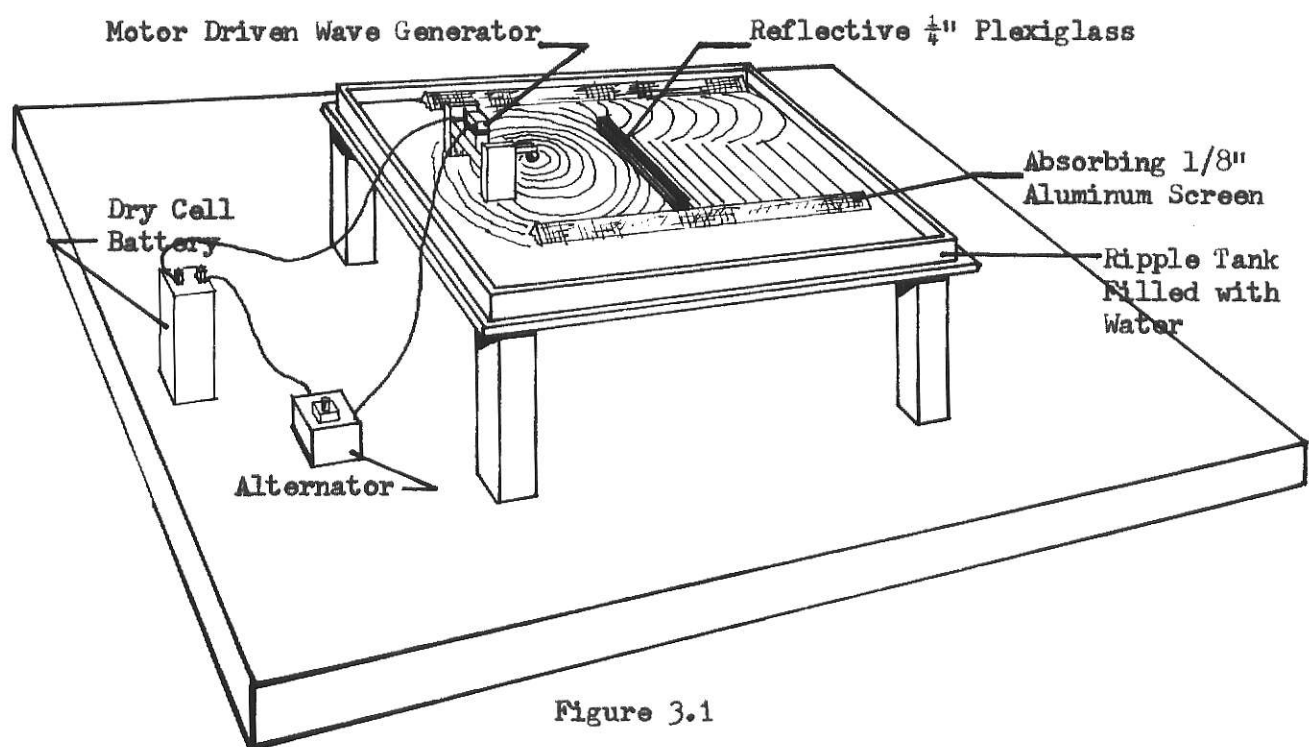


Figure 3.1

RIPPLE TANK EXPERIMENT

of an overhead projector, the wave shadow patterns were observed and studied. The wave motion was created by a direct current electric driven point source. (See Figure 3.1 Plate X)

Absorbing surfaces and dampeners were 1/8 inch aluminum screen wire folded and secured to create the scaled down room boundaries, of the floor and ceiling, used in the ripple tank.

Reflecting surfaces of $\frac{1}{4}$ inch thick formed plexiglass were used to simulate the hard surfaces of typical partial dividers used in a landscaped office space.

While the absorbing and reflecting materials were in the partially water-filled ripple tank, the electric driven point source was generating waves and this was projected on a screen by an overhead projector. Various combinations of the materials and their shapes were used, and the resulting high and low frequency wave patterns were observed.

Figure 3.2 set represents sections of a space in which the ceiling height is nine feet and the floor and ceiling materials are absorbent. The point source represents a seated person and the concentric circles represent the sound wave motion. Higher frequency wave patterns have shorter distances between their waves than lower frequencies. The interference line represents the boundary of wave motions that interact with each other. Barriers used are of various shapes and sizes and represent reflective surfaces.

Observation

The various shapes and sizes of barriers used, in relation to the point source, produced varying effects of diffraction and reflection

of waves in a fluid medium. This medium represents the fluid medium of air that sound is transmitted through. Representation of the fluid medium (air) in this manner can only produce a two dimensional pattern.

The majority of the barriers allowed the wave patterns to flow over and down into the adjacent space. These would, therefore, represent sound being diffracted or reflected into the adjacent space. Depending on the distance these diffracted or reflected waves penetrated, the adjacent space constituted their degree of distraction to the worker in this adjacent space. If the diffracted or reflected waves penetrated into the adjacent space below a distance of six feet from the barrier and six feet above the floor then these waves were considered to distract the adjacent space worker. The barriers in Plates XII and XIII were considered not to meet these qualifications and, therefore, suggest an effective sound attenuating barrier.

Conclusion

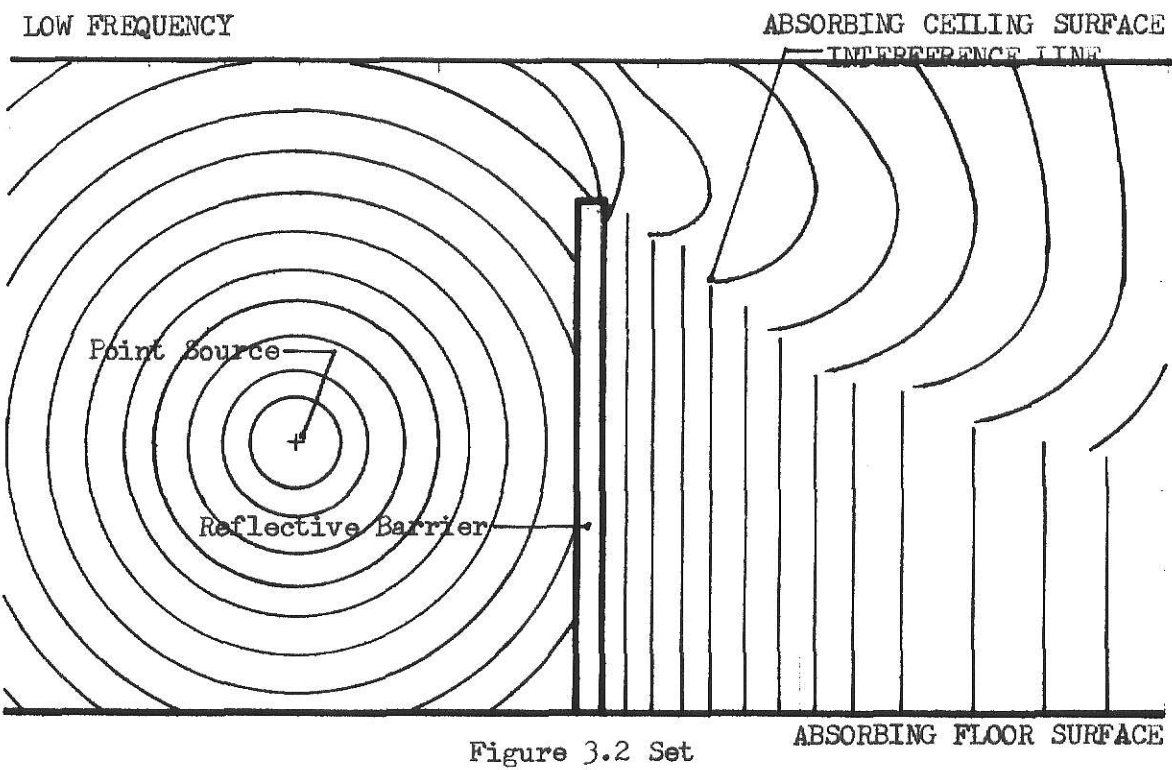
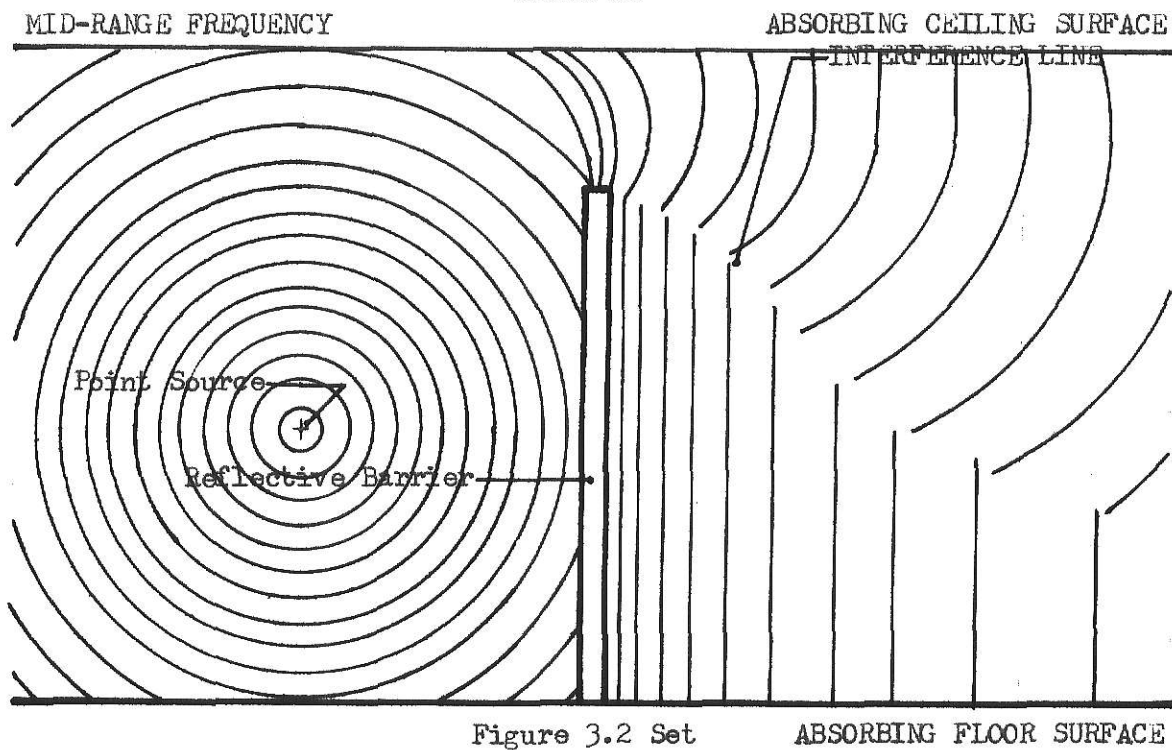
Evidence from the graphs show that generally mid-range frequency wave patterns have lines of interference and smaller angles of inclination with the ceiling than have the lower frequency wave patterns.

Low frequency sounds are commonly encountered in background noises such as motor driven fans, etc. and result in undesirable hum and noise. The lower frequencies contribute to speech quality but add little to intelligibility and are difficult to reflect effectively. The latter characteristic can be seen in most of the low frequency graphs' wave motions.

Mid-range frequency sounds are less affected by normally encountered architectural dimensions and not as readily absorbed by materials usually used for absorption. These frequencies effectively mask speech if they are loud and are vital to speech intelligibility.

Controlling the characteristics of mid-range frequency sounds is the criteria that will be the most beneficial in the reduction of sound intensity which contributes to speech intelligibility. The shapes and types of barriers used must be designed to redirect the wave motion in such a way as to make most efficient use of absorbing surfaces. The shapes that may achieve this are represented in Plates XXII and XXIII. Plan views that may best reduce sound levels by reflection are shown on Plates XVI and XVII.

PLATE XI



Scale: $\frac{3}{8}" = 1'0"$

**THIS BOOK
CONTAINS
NUMEROUS PAGES
WITH THE ORIGINAL
PRINTING BEING
SKEWED
DIFFERENTLY FROM
THE TOP OF THE
PAGE TO THE
BOTTOM.**

**THIS IS AS RECEIVED
FROM THE
CUSTOMER.**

MID-RANGE FREQUENCY

ABSORBING CEILING SURFACE

INTERFERENCE LINE

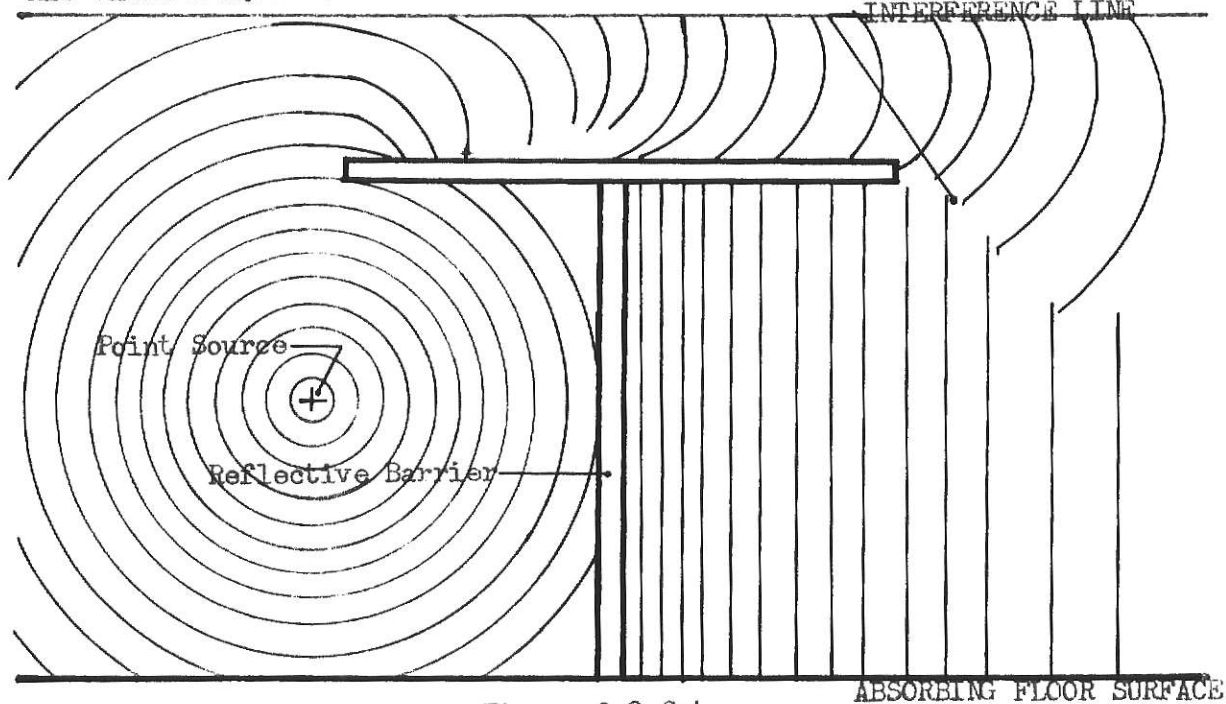


Figure 3.2 Set

LOW FREQUENCY

ABSORBING CEILING SURFACE

INTERFERENCE LINE

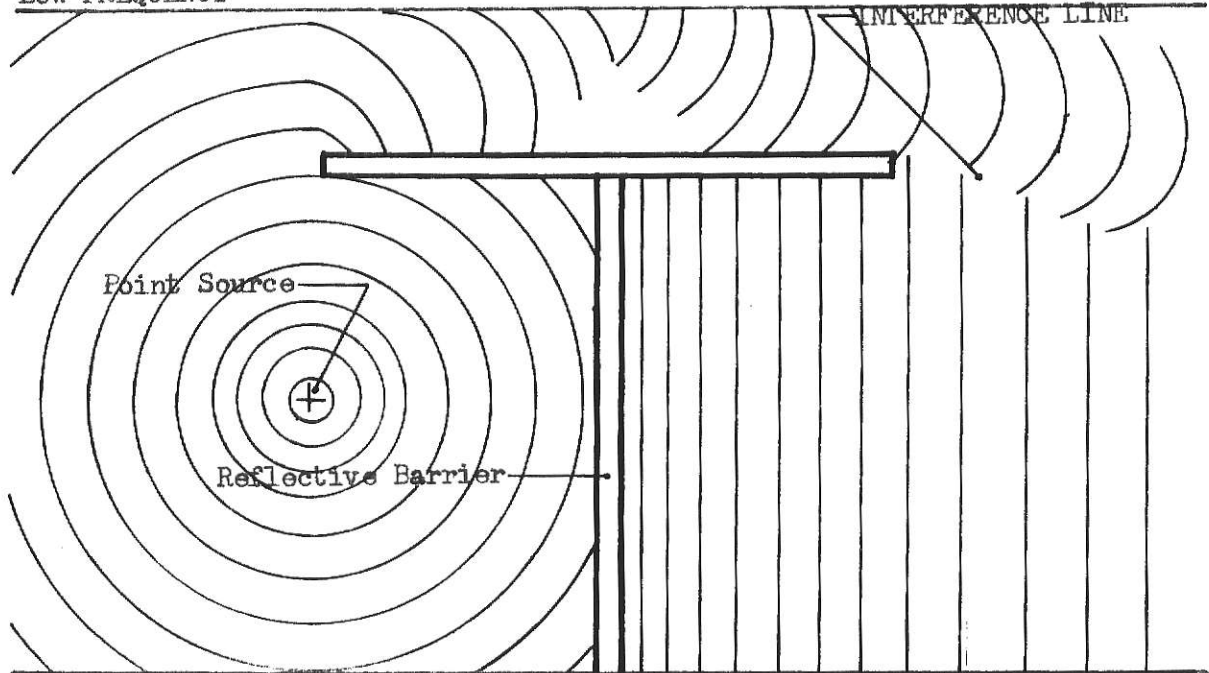


Figure 3.2 Set

ABSORBING FLOOR SURFACE

Scale: $\frac{3}{8}'' = 1'0''$

MID-RANGE FREQUENCY

PLATE XIII

ABSORBING CEILING SURFACE

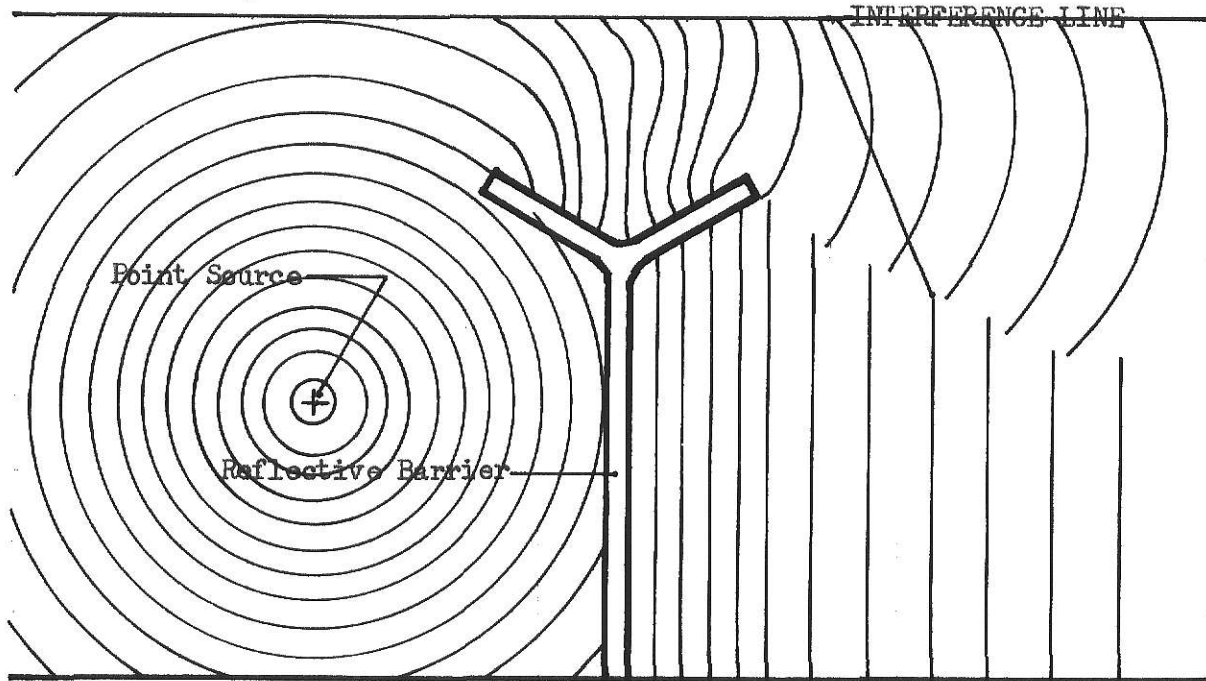


Figure 3.2 Set

ABSORBING FLOOR SURFACE

LOW FREQUENCY

ABSORBING CEILING SURFACE

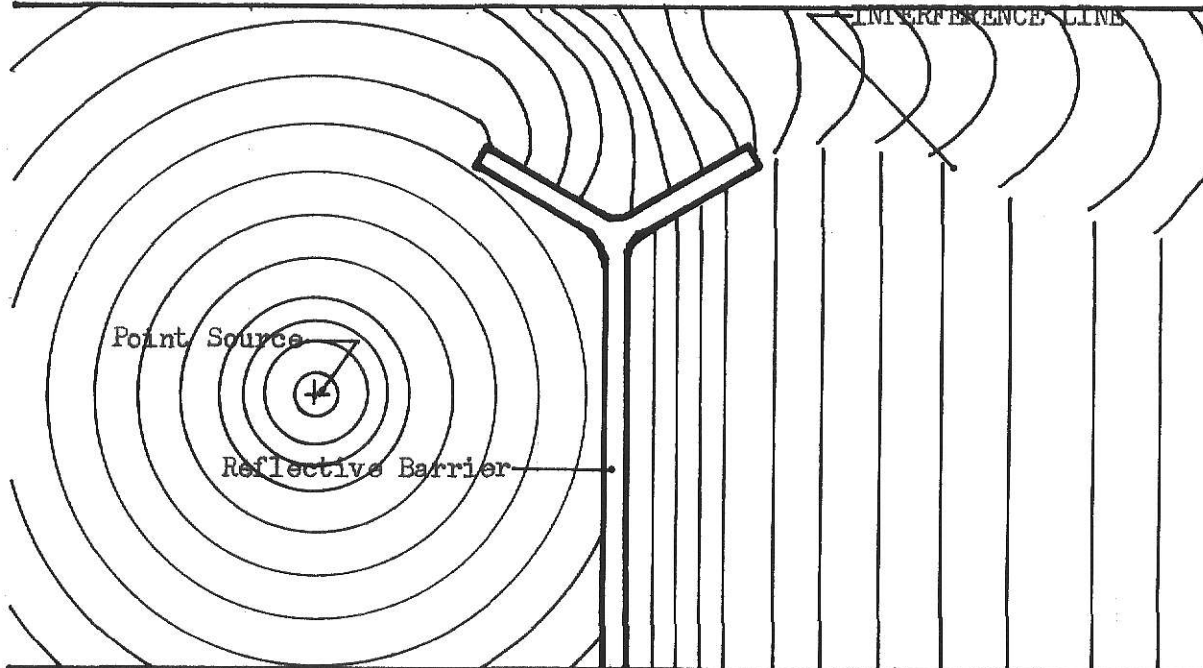


Figure 3.2 Set

ABSORBING FLOOR SURFACE

Scale: $3/8" = 1'0"$

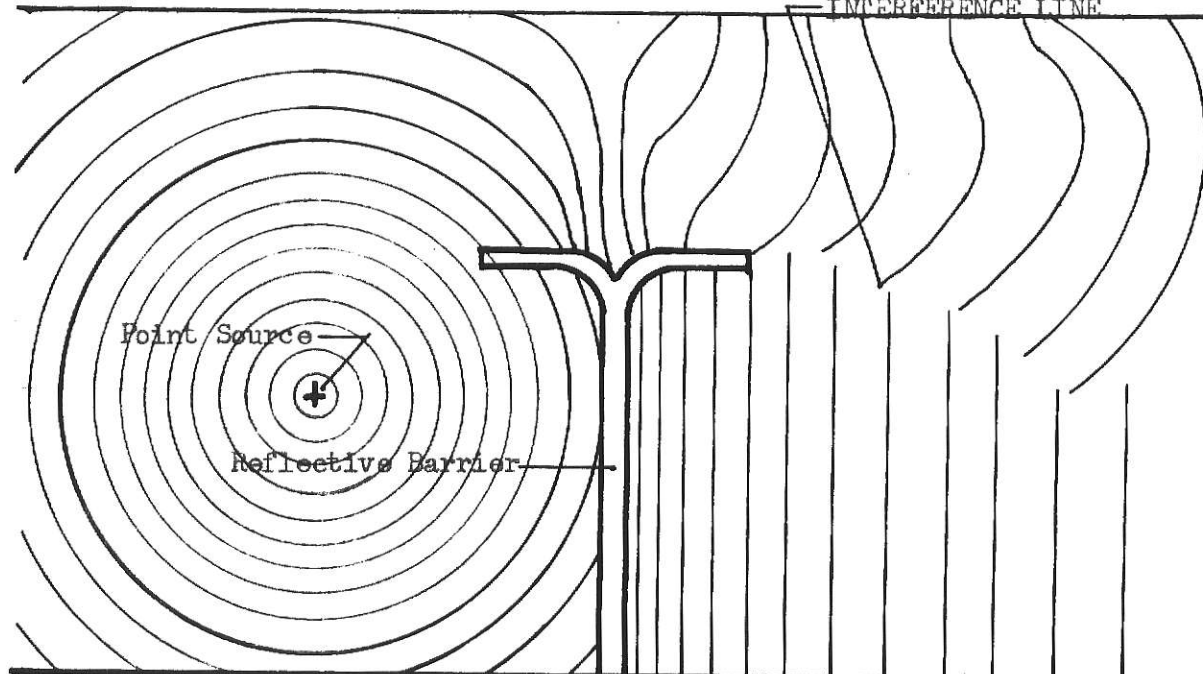


Figure 3.2 Set

ABSORBING FLOOR SURFACE

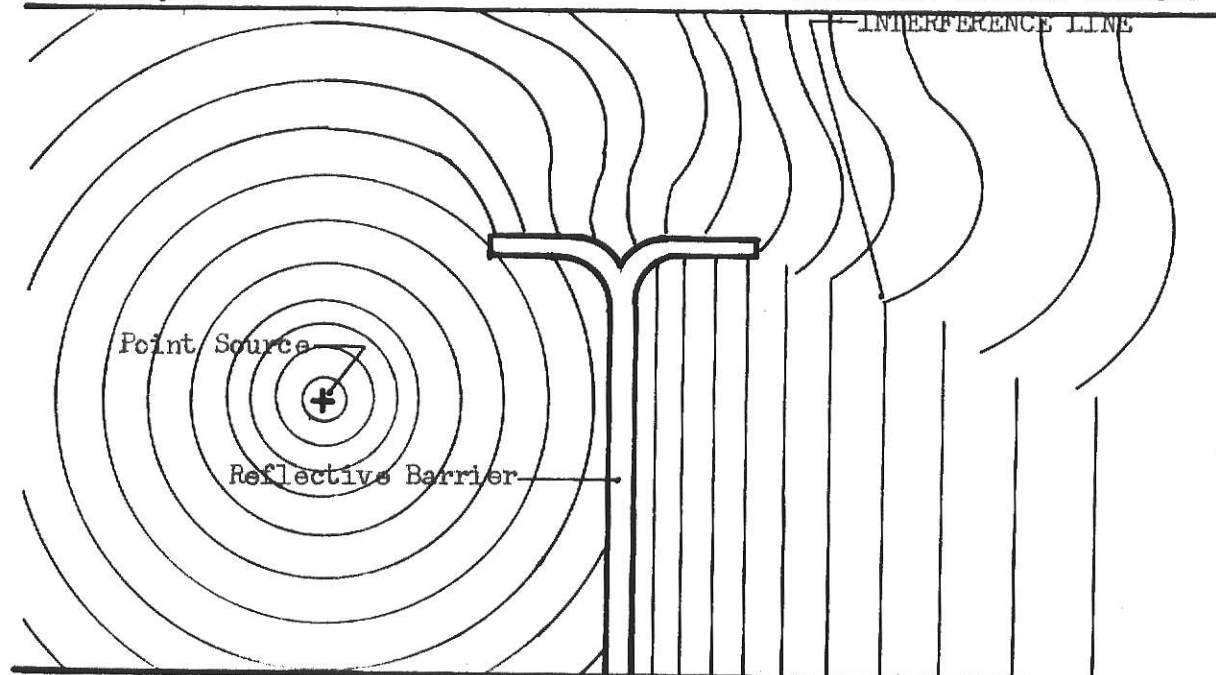


Figure 3.2 Set

ABSORBING FLOOR SURFACE

Scale: $\frac{3}{8}'' = 1'0''$

MID-RANGE FREQUENCY

ABSORBING CEILING SURFACE

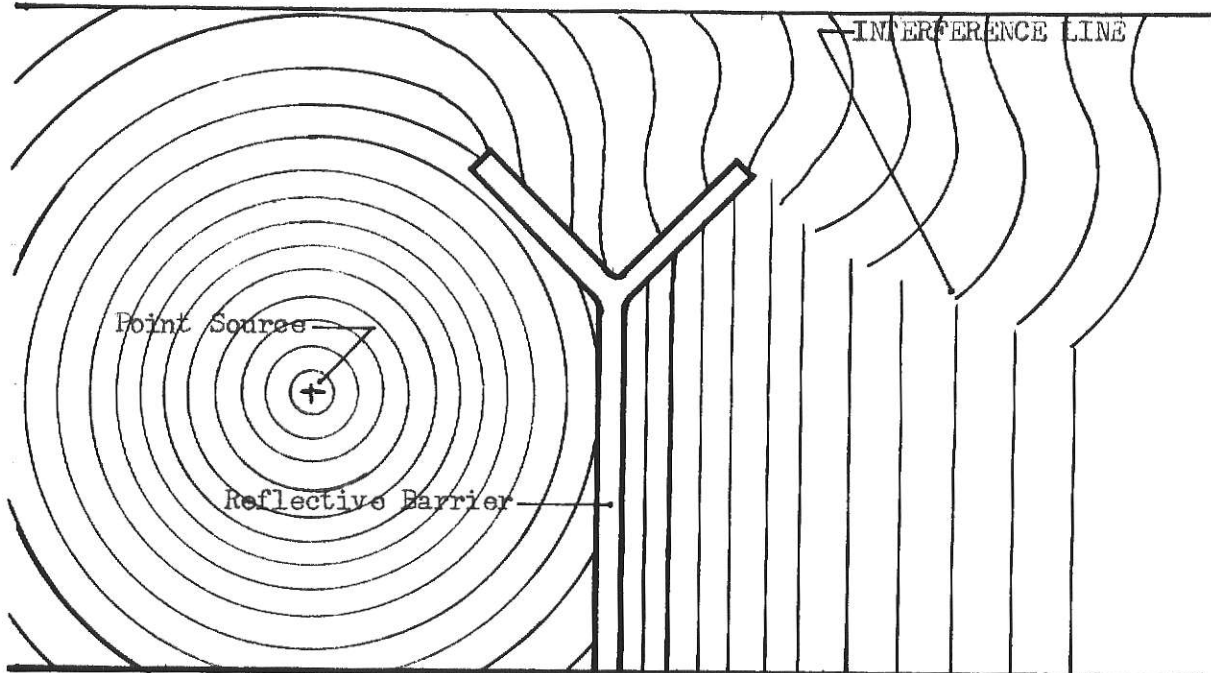


Figure 3.2 Set

ABSORBING FLOOR SURFACE

LOW FREQUENCY

ABSORBING CEILING SURFACE

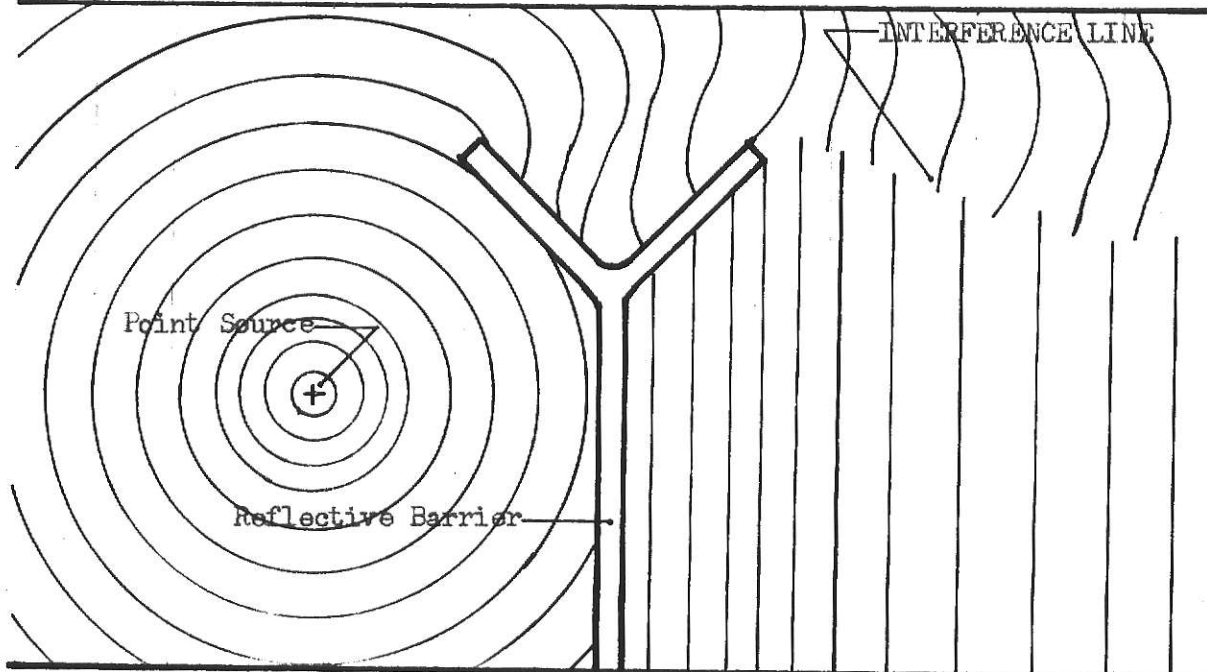


Figure 3.2 Set

ABSORBING FLOOR SURFACE

Scale: $3/8" = 1'0"$

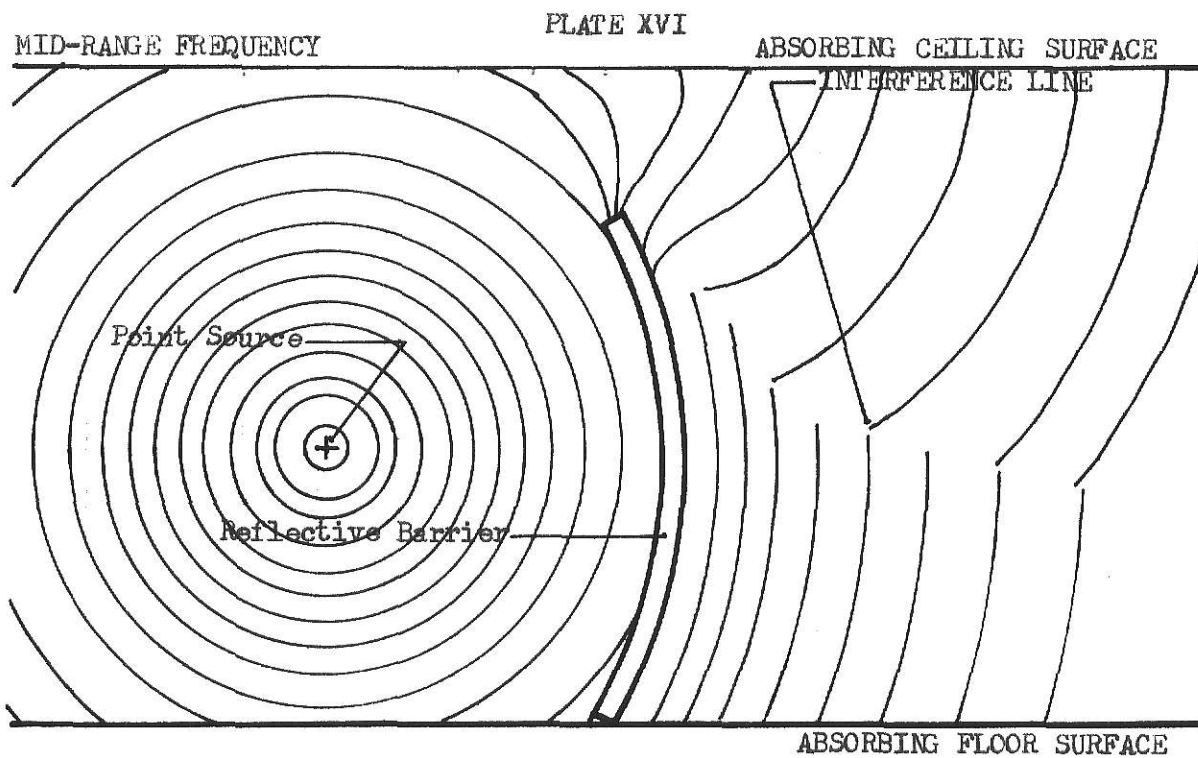


Figure 3.2 Set

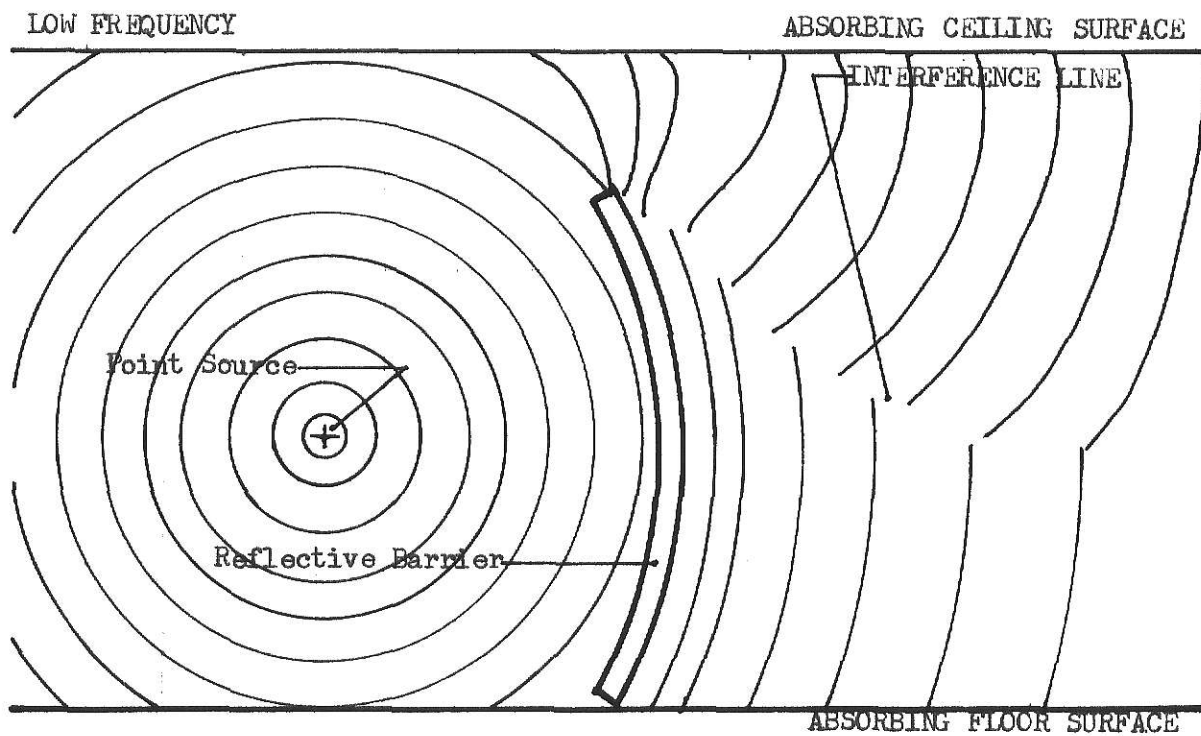


Figure 3.2 Set

Scale: $\frac{3}{8}" = 1'0"$

PLATE XVII

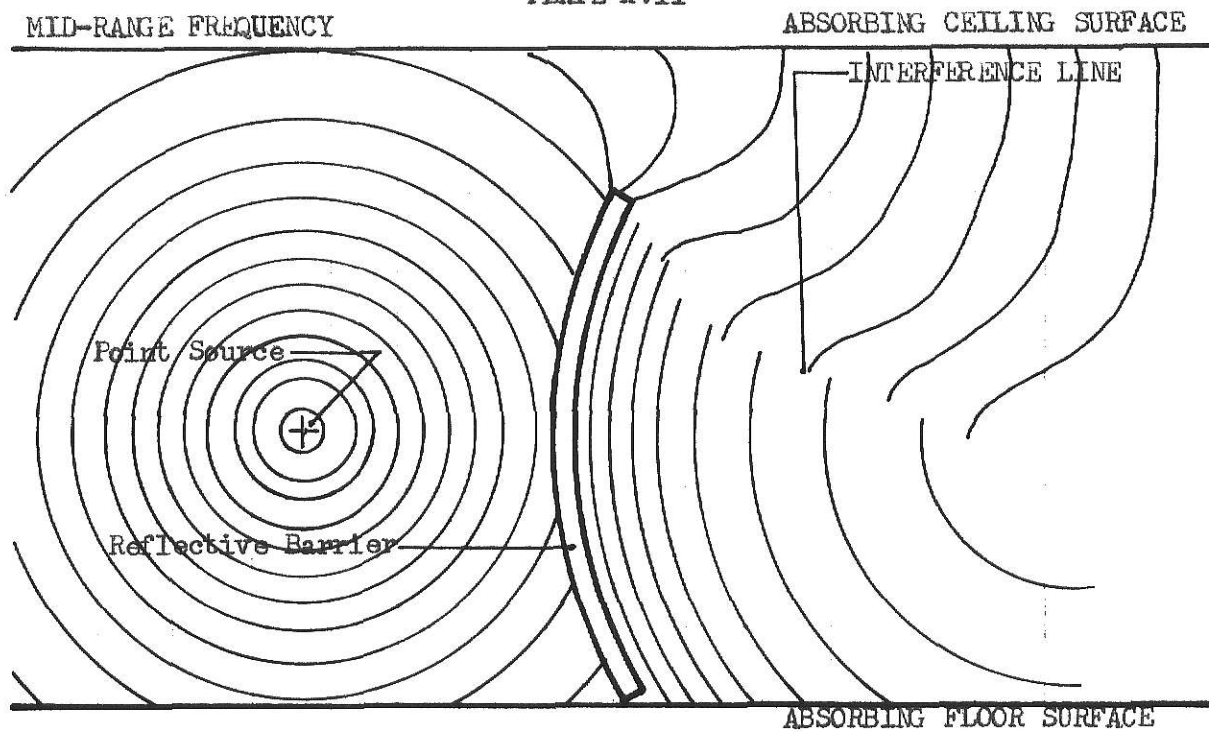


Figure 3.2 Set

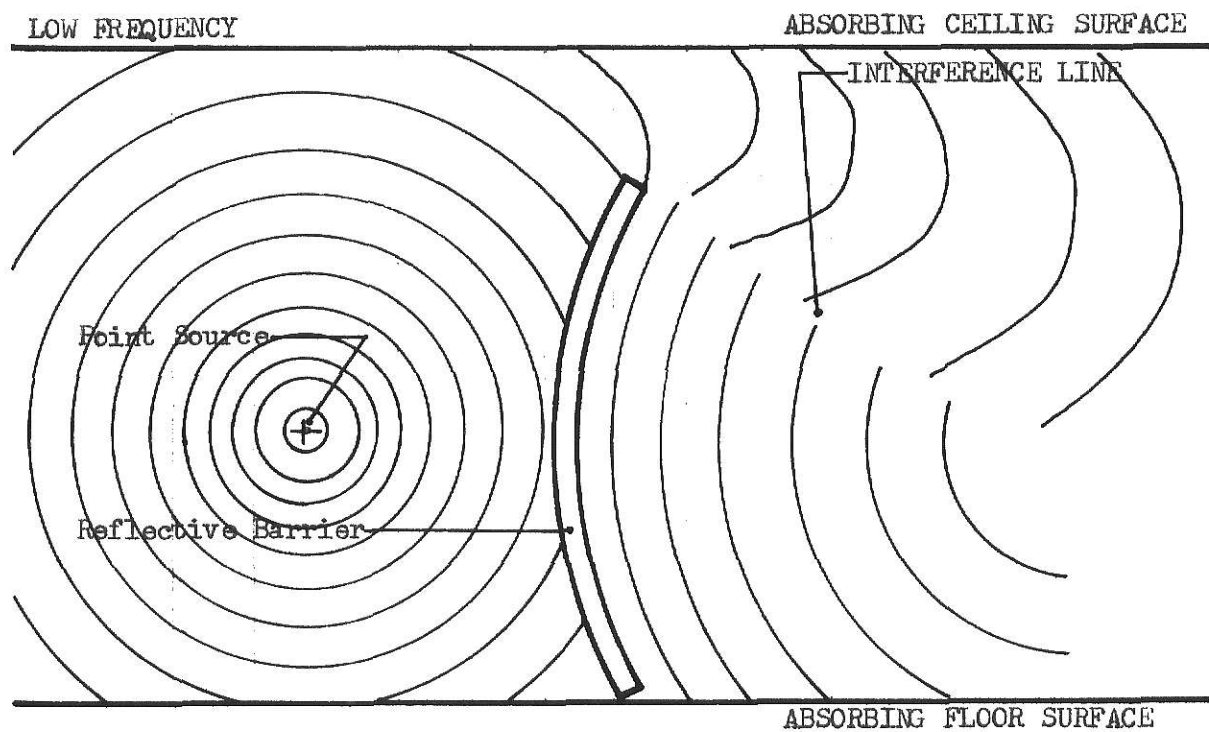


Figure 3.2 Set

Scale: $\frac{3}{8}'' = 1'0''$

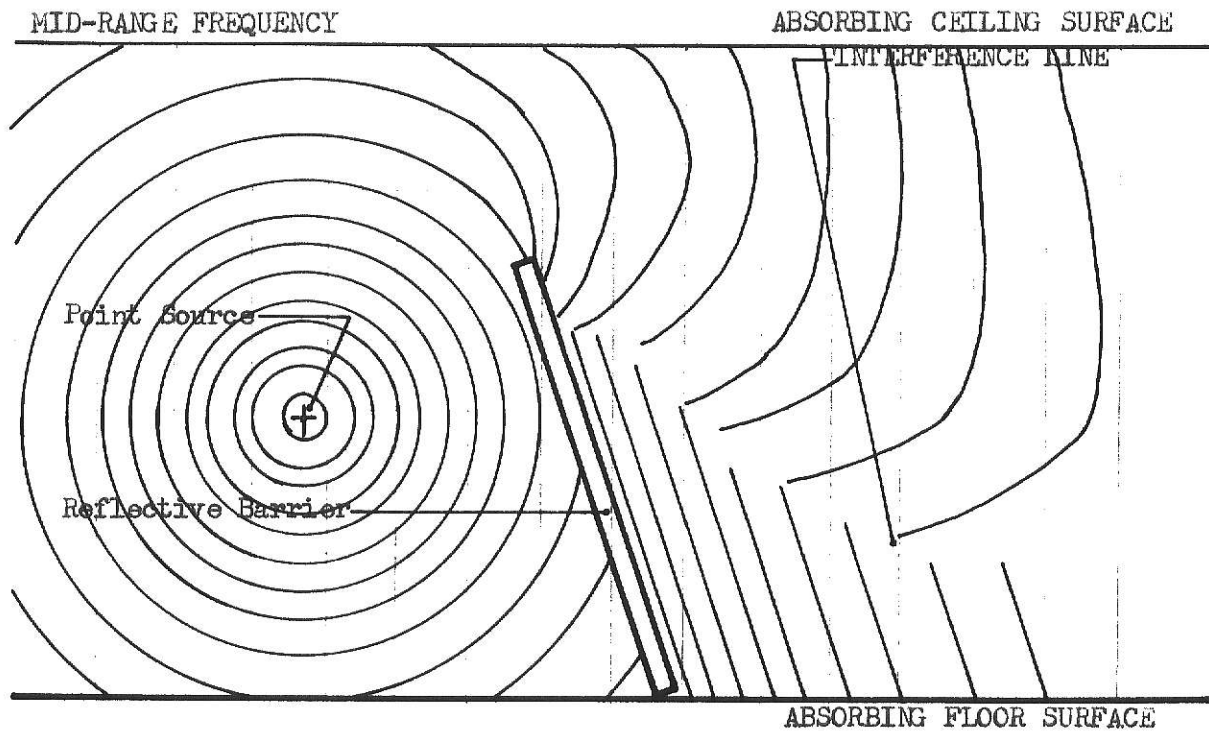


Figure 3.2 Set

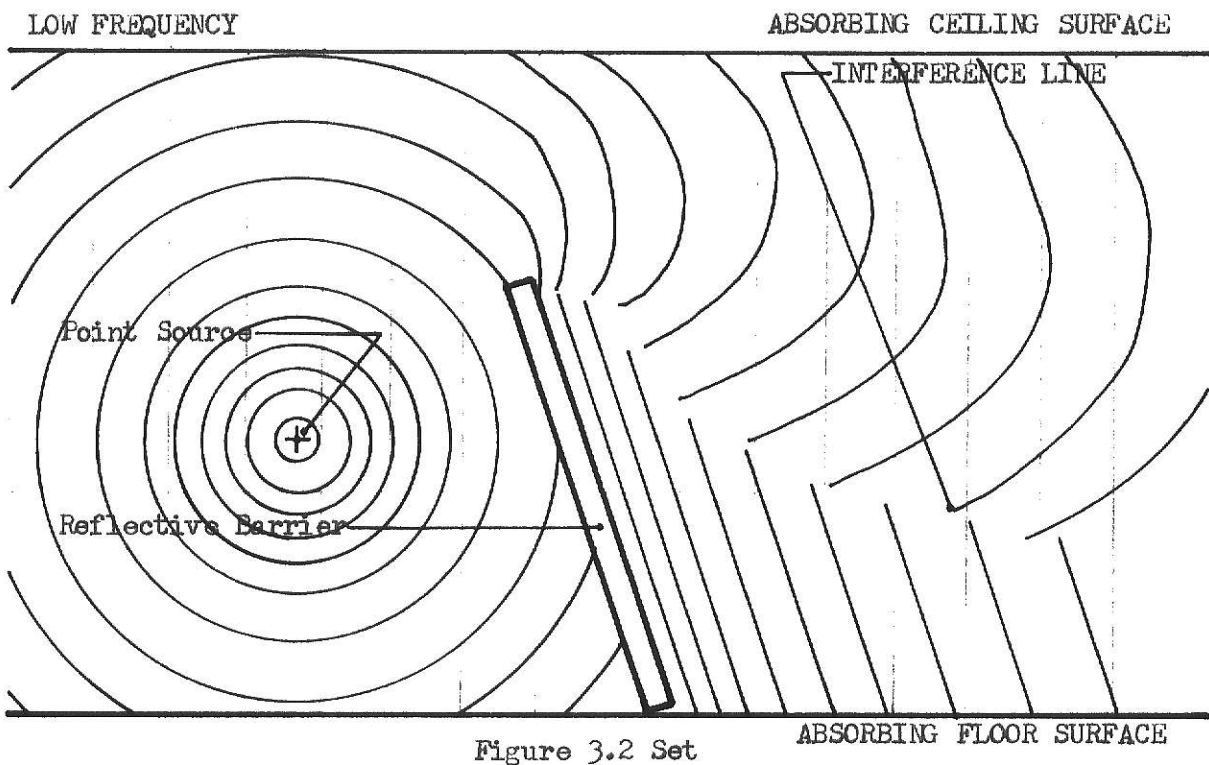


Figure 3.2 Set

Scale: $\frac{3}{8}'' = 1'0''$

MID-RANGE FREQUENCY

PLATE XIX

ABSORBING CEILING SURFACE

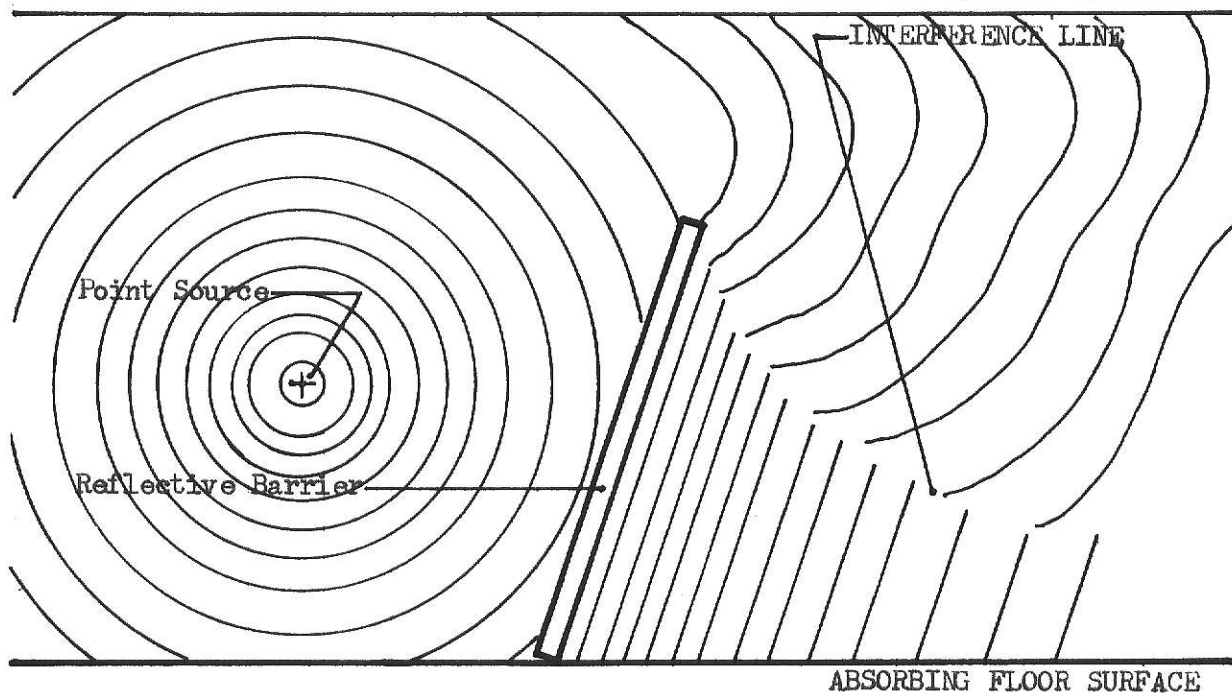


FIGURE 3.2 Set

LOW FREQUENCY

ABSORBING CEILING SURFACE

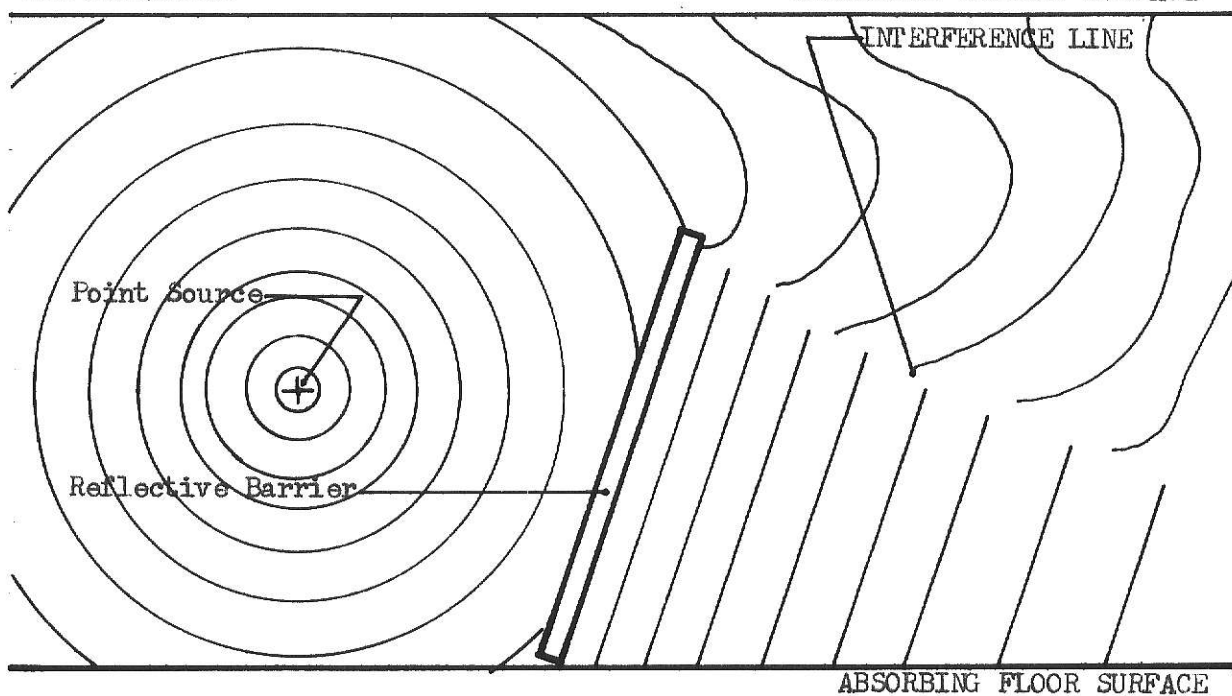


Figure 3.2 Set

Scale: $\frac{3}{8}'' = 1'0''$

Test II

TEST OF SOUND FLOW AROUND SIMPLE LANDSCAPE PARTITION

Purpose

The theoretical findings in Test I are a basis for this test involving the measurement of sound pressure levels located around a simple barrier, which would simulate conditions of an office landscaped space. Physically generating a point source sound wave and constructing a barrier to measure actual sound pressure levels enables sound wave motions to be plotted. These values can either aid in proving or disproving the theoretical findings of the first test.

Technique and Equipment

A space was chosen which could be tested with relative ease. The Kansas State Union second floor corridor was chosen because the conditions there best simulated an economical landscaped office space, containing a large open space with a low, acoustical tiled suspended ceiling and carpeted floor. The partition was assembled by sectioning together eight four-foot square acoustical panels having a thickness of four inches. The partial partition was constructed with 3/16 inch perforated pegboard front, surfaces backed by three inches of fiberglass acoustical batting and a solid wood back. Side panels of 3/4 inch fiber board covered with burlap were used as screens on either side of the partial partition. These were assembled as shown in Figure 3.3 Plate XX.

The noise was produced by a noise generator which was amplified by a Relistic 5 Watt Amp Ampio amplifier. Two sound level meters were

PLATE XX

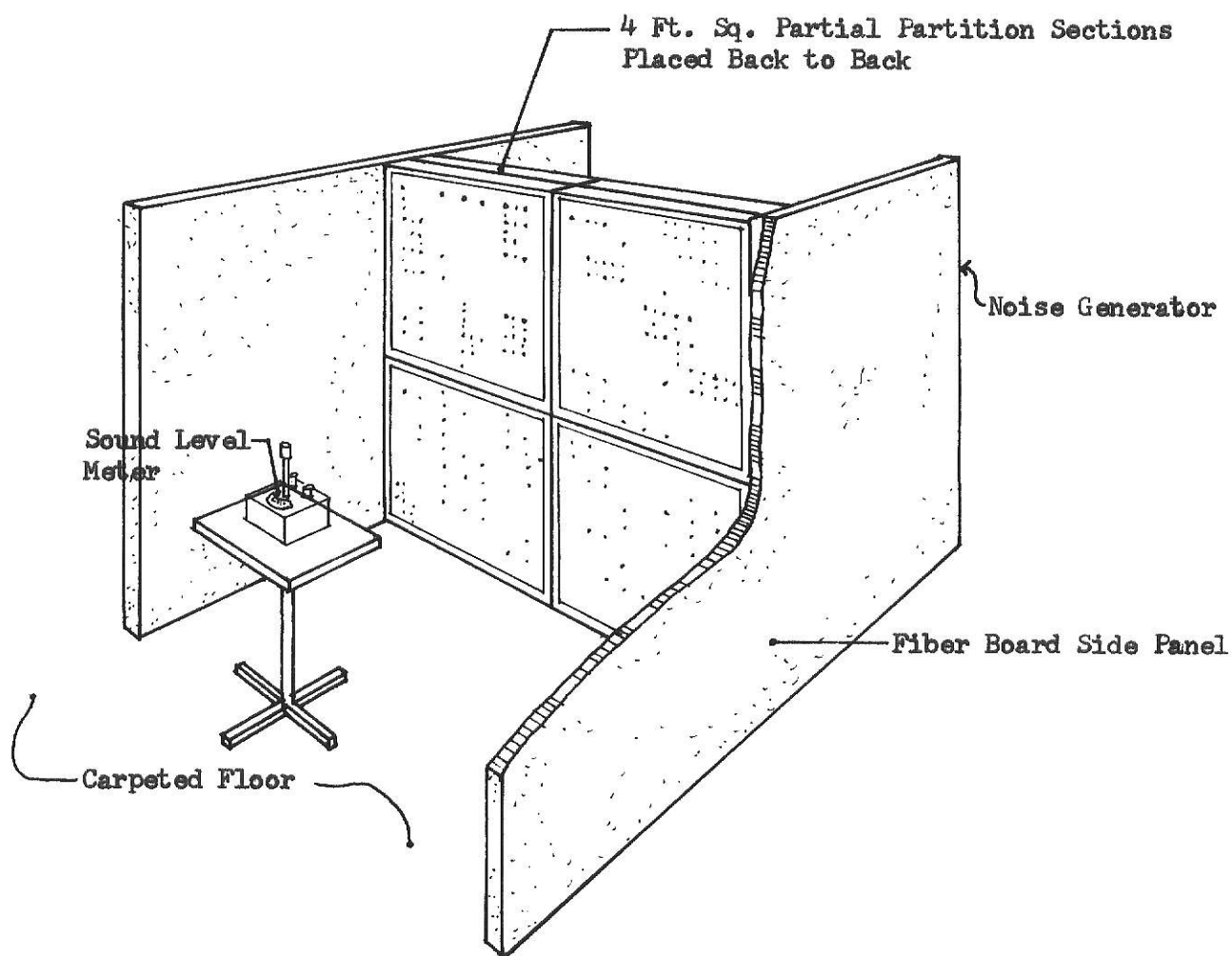


Figure 3.3

Perspective of Equipment Used in Test II

Ceiling Height -- 9'6"

Partition Height -- 8'0"

Depth of Side Panels -- 8'0"

Source Located 36" Height at a Distance of 36" from Side Panel and 45" from Partial Partition.

used, one to check the source output and the other to check the sound pressure level by a simulated receiver in an adjacent position. A portable octave band analyzer with an extension condenser microphone enabled sound pressure level readings on the C - scale to be taken at intervals shown on plan and section graphs, Plates XXII-XXVII. Spot check readings were taken on the A - scale, Plate XXI. Sound wave contours were plotted to depict their motion in relationship to this particular test's situations.

The following graphs represent plans and sections of sound pressure level contours plotted from the sound pressure level readings taken with the octave band analyzer. The numbers represented are decibel units measured on the C - scale, unless labeled otherwise. The ceiling height represented is nine feet six inches. The sound pressure level emitted by the point source was 75 decibels. The respective locations of the source and a simulated receiver are marked.

The room used is a good quiet room with a background noise level of 40-42 decibels on the A - scale and 63-65 decibels on the C - scale. Such conditions represent a quiet office.

Observations

The drawings depict the generally concentric forms of wave motion from a point source. This is best shown by the contours closest to the source as in Plates XXV and XXVI. From the sections, the sound pressure level contours depict the diffraction of sound over the partial partitions. Both plans and section drawings show that sound

PLATE XXI

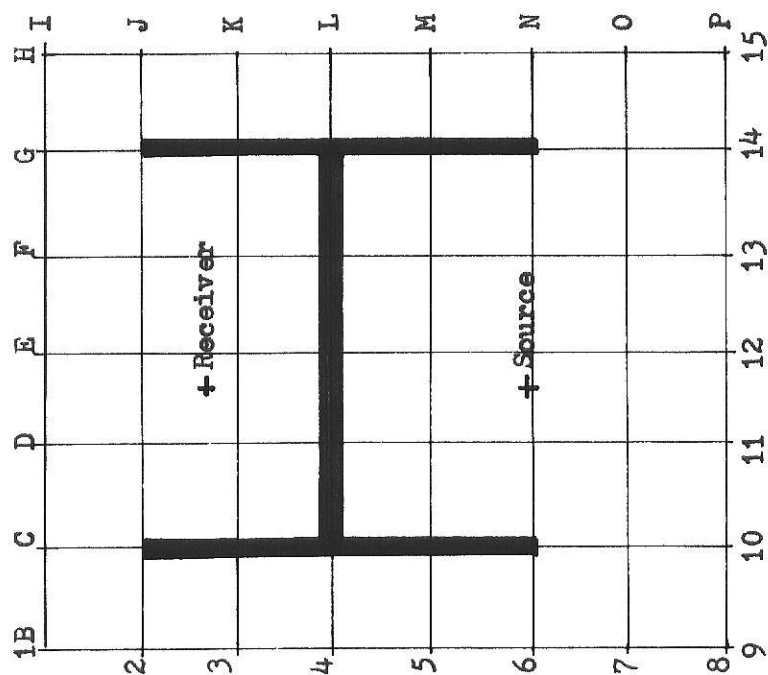


Figure 3.4
Plan of Partial Partition Used
in Test II

Scale: $\frac{1}{4}" = 1'0"$

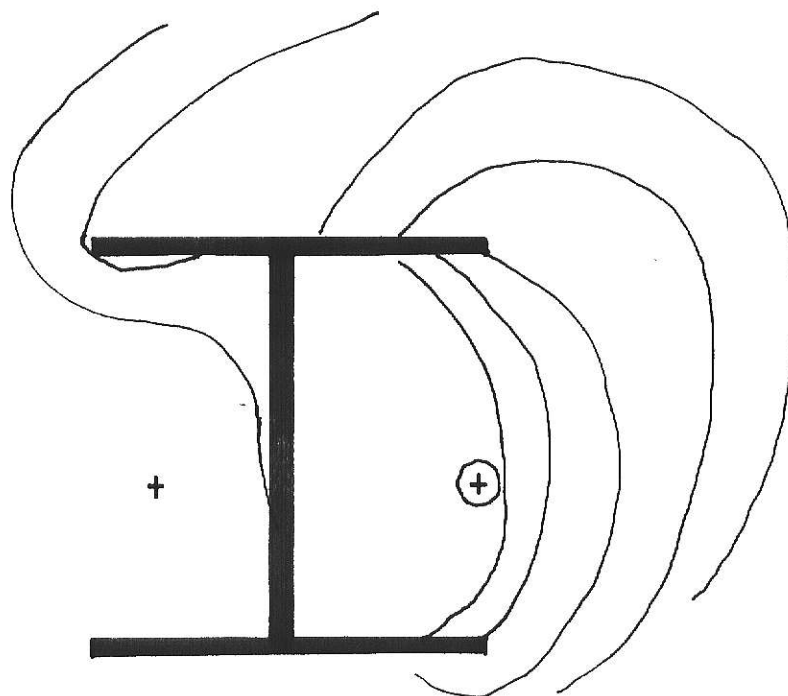


Figure 3.5
A - Scale Spot Check Readings

levels are absorbed by the partial partition material and very little attenuation is achieved except it was noted at frequency above 500 cycles. A sound level of about 65 decibels is the general overall effect of the source that travels over the partial partition. This is a ten decibel reduction and one that is physically noticeable by subjective observation. What is very noticeable by subjective observation is that the audibility of speech is not affected. Conversation at low intensity can be overheard on the adjacent side of the partial partition.

Conclusion

It was clearly observed that this type of partial partition, though effective in reducing sound pressure level, does not stop one's ability to understand conversations taking place on the opposite sides of the partition.

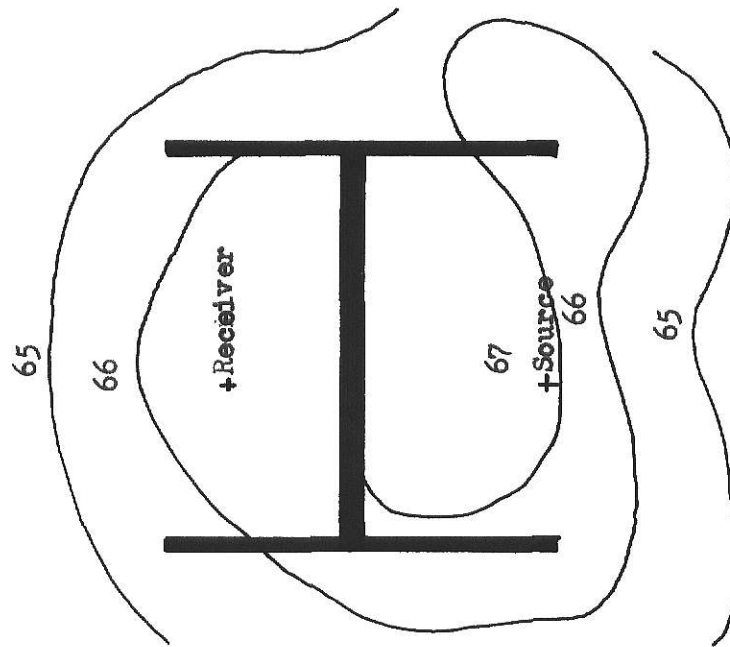


Figure 3.6 Set

Plan of Test Space with 6 Ft.
Elevation contours Weighted on
dBc Scale.

Scale: $\frac{1}{4}" = 1'0"$

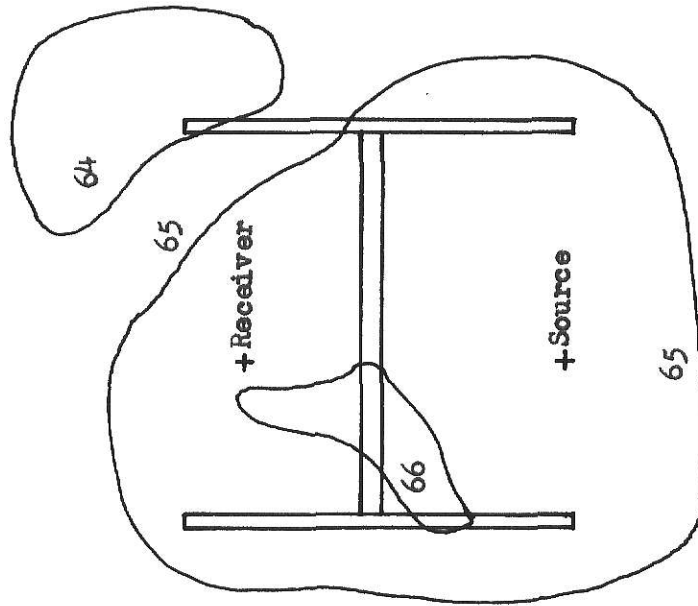


Figure 3.6 Set

Plan of Test Space with 9 Ft.
Elevation Contours weighted on
dBc Scale.

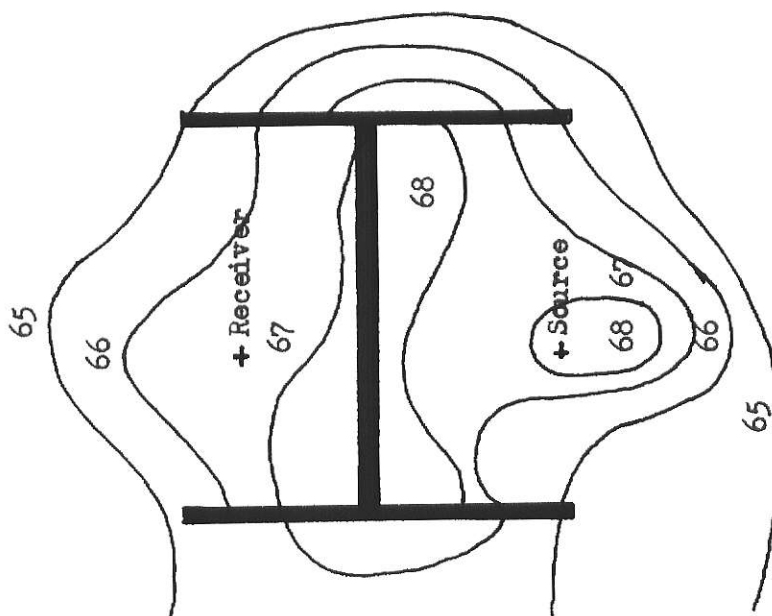


Figure 3.6 Set
Plan of Test Space with one foot
Elevation Contours weighted on dBc Scale.
Scale: $\frac{1}{4}" = 1'0"$

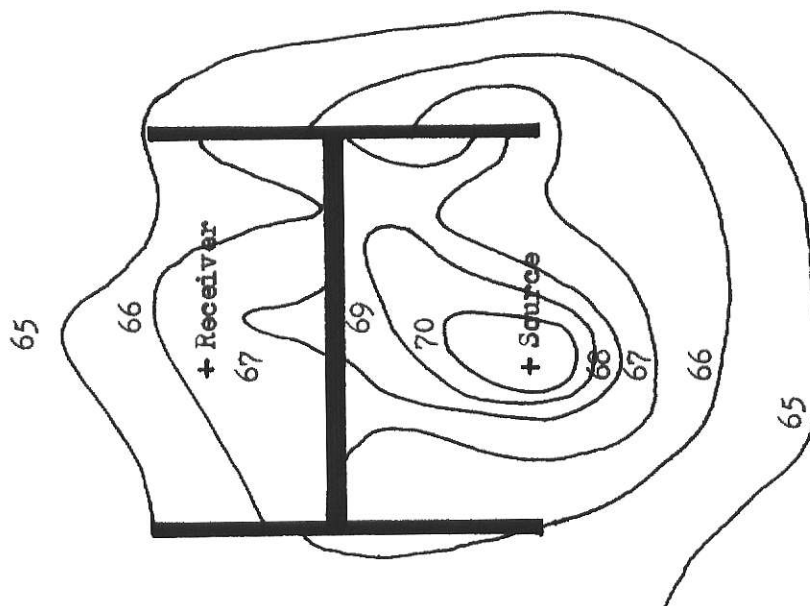
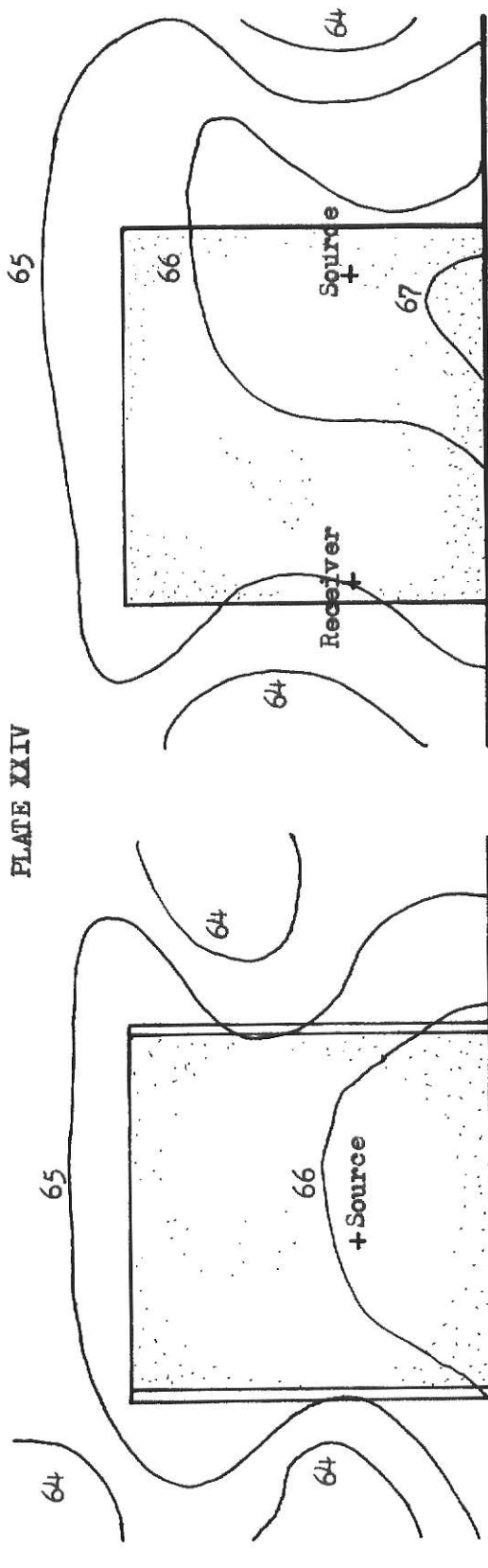
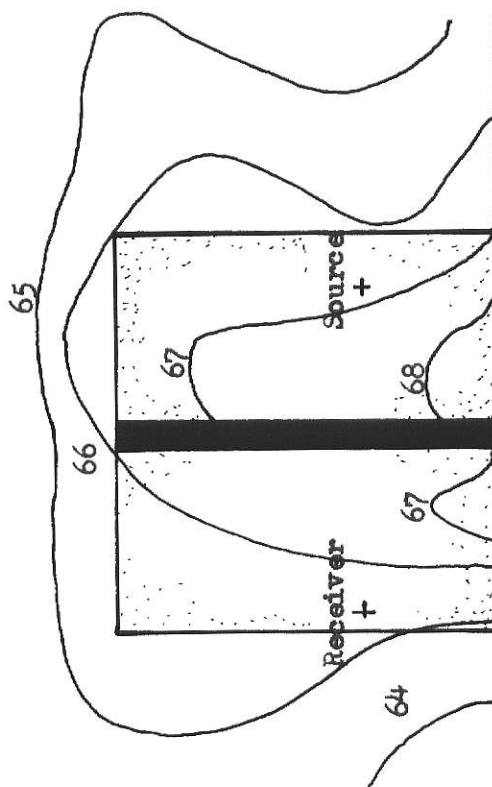


Figure 3.6 Set
Plan of Test Space with 3 foot Elevation
Contours weighted on dBc Scale

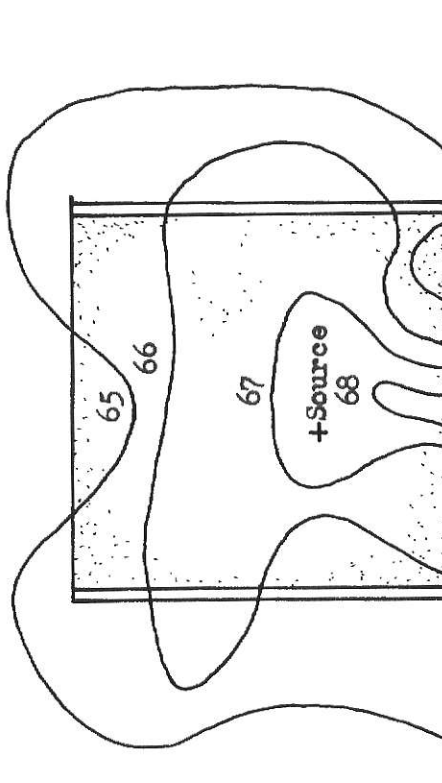


Section 8-P
Figure 3.6 Set

Section B-9
Figure 3.6 Set

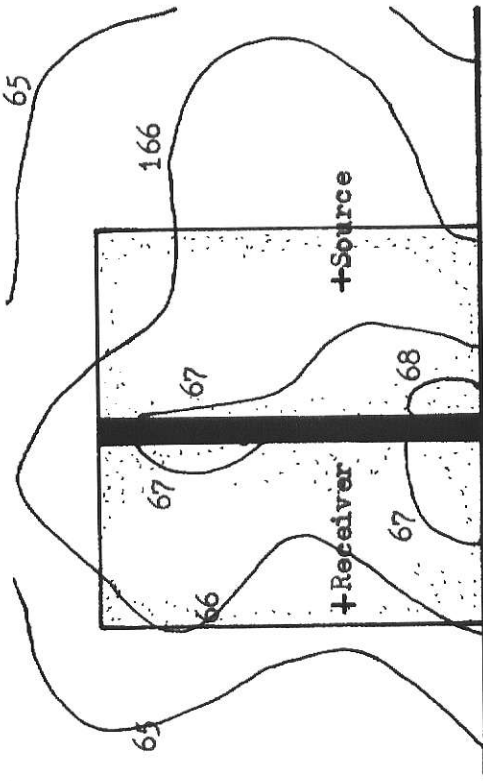


Section C-10
Figure 3.6 Set

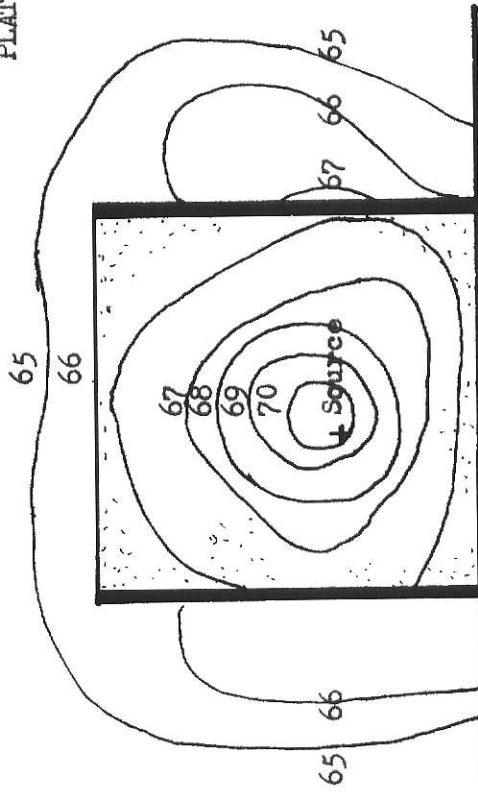


Section 7-0
Figure 3.6 Set

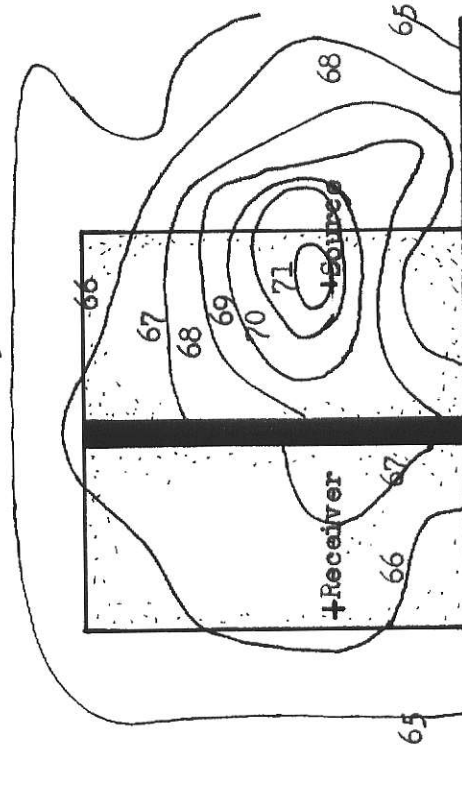
Note: All the above figures represent their respective sections weighted on dBc Scale.
Scale: $\frac{1}{4}$ " = 1'0"



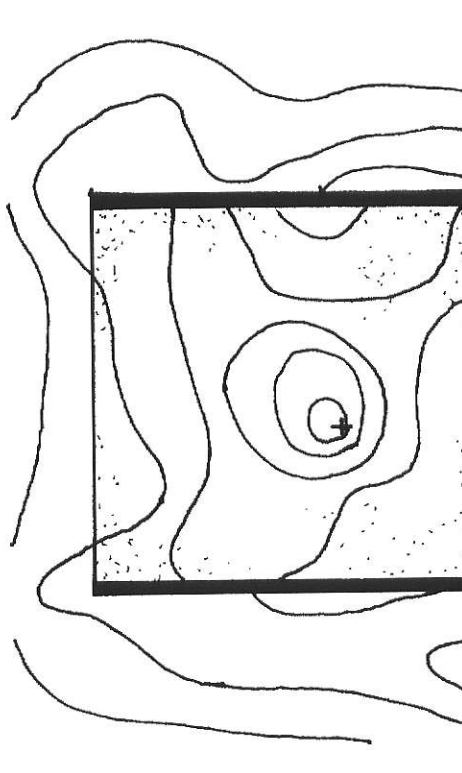
Section D-11
Figure 3.6 Set
65



Section 6-N
Figure 3.6 Set

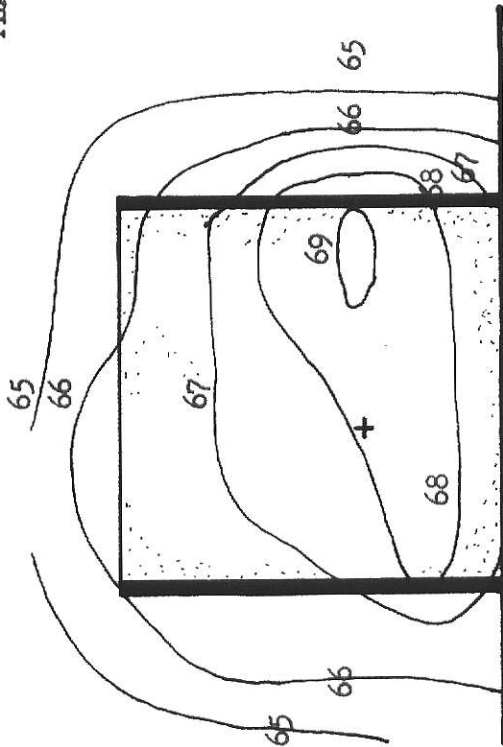


Section E-12
Figure 3.6 Set

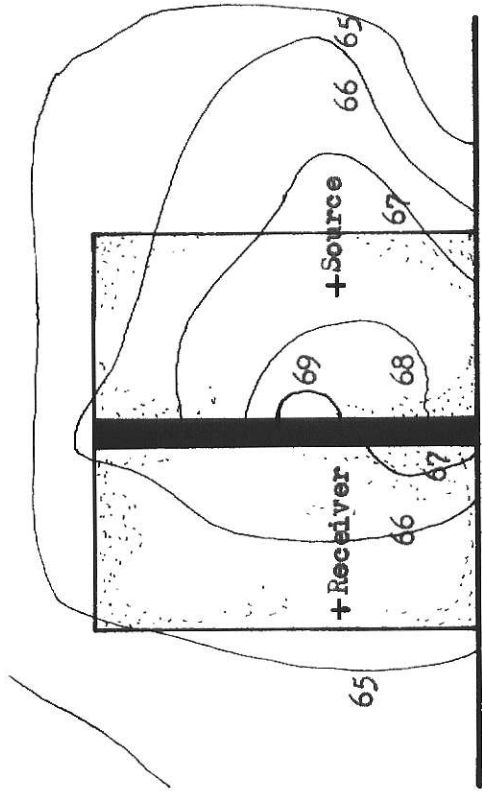


Section 5-M
Figure 3.6 Set

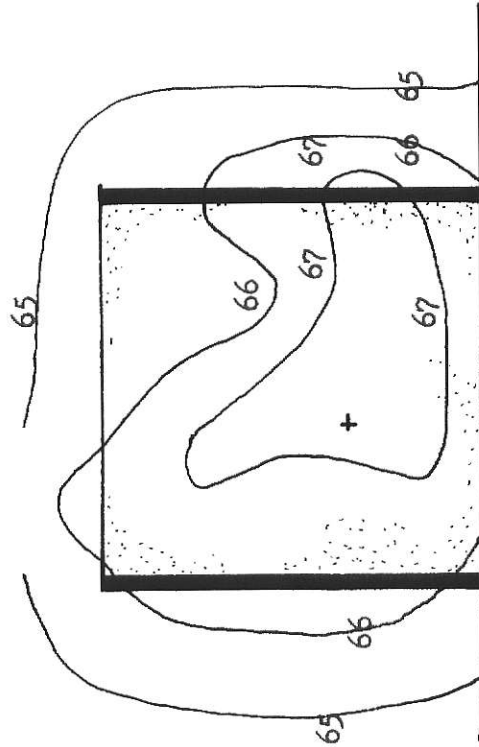
Note: All the above figures represent their respective sections weighted on db C Scale.
Scale: $\frac{1}{4}" = 1'0"$



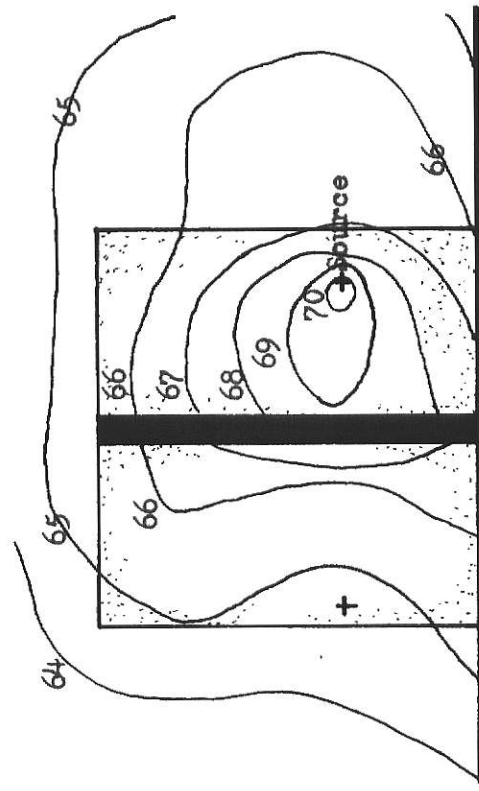
Section 4-L (source side)
Figure 3.6 Set



Section F-13
Figure 3.6 Set



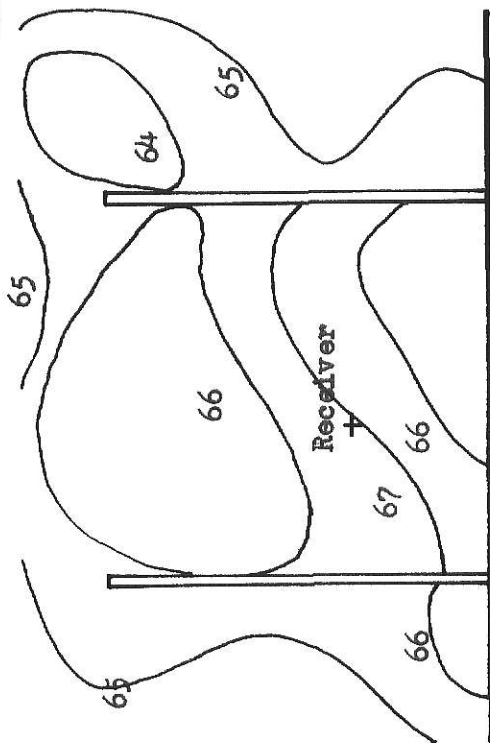
Section L-4 (Receiver Side)
Figure 3.6 Set



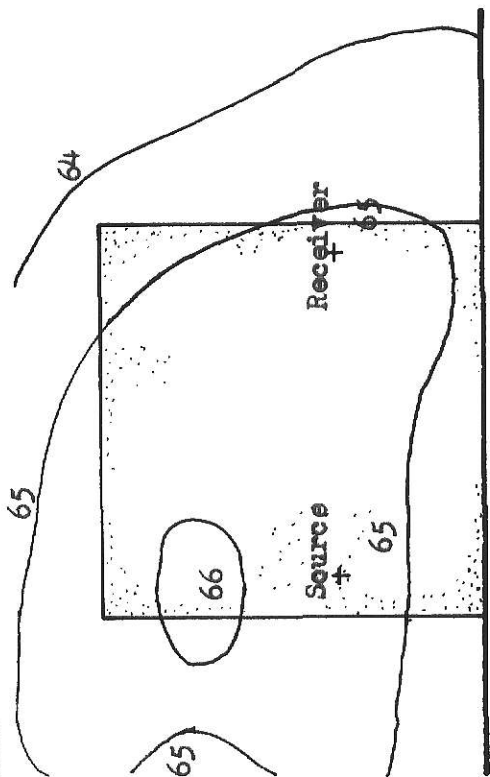
Section G-14
Figure 3.6 Set

Note: All the above figures represent their respective sections weighted on db C Scale.
Scale: $\frac{1}{4}$ " = 1'0"

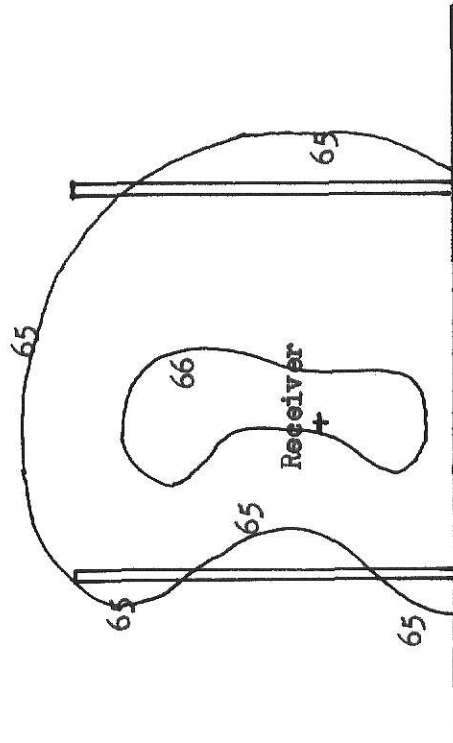
PLATE XXVII



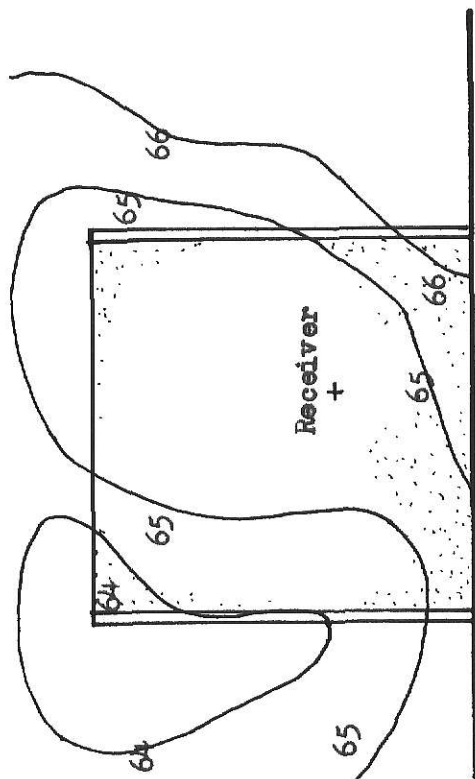
Section 3-K
Figure 3.6 Set



Section 15-H
Figure 3.6 Set



Section 2-J
Figure 3.6 Set



Section I-1
Figure 3.6 Set

Note: All the above figures represent their respective sections weighted on db C Scale.
Scale: $\frac{1}{4}$ " = 1'0"

Test IIIPLANNING DEPARTMENT OFFICE STUDY

Purpose

Investigate point source sound wave motion and sound pressure levels in a subdivided office space and how these are affected by various acoustical treatments and conditions involving changes in ceiling heights, the addition of acoustical ceiling materials, absorbing floor covering and floor-to-ceiling enclosures.

Technique and Equipment

Data was recorded in four stages. The first stage was the existing condition of a space divided by eight foot high partial plaster partitions connected and supported by metal tubular supports. The walls and ceiling defining the overall space were plaster and the floor surfaces were tongue and groove wooden flooring. Existing office furniture was left in its normal position throughout all four stages. (See Figure 3.7 Plate XXVIII) The space was entered through double wooden solid core doors. On the opposite side of the space were double hung windows. A noise source generated random noise from a point in space 'A' and sound pressure levels were recorded with the use of the same equipment mentioned in Test II. Sound pressure level readings were recorded and sound contours plotted. (See Plate XXX)

In stage two, conditions remained the same as in stage one except the ceiling was lowered to a height of nine feet and consisted of two foot by four foot acoustical tiles (lay-in type) suspended in a metal grid system.

In stage three, the floor surface was changed to a carpet with rubber backing while the other conditions of stage two remained the same. Sound pressure level readings were recorded and sound contours plotted. (See Plate XXXI)

In stage four, the conditions of stage three were kept constant except the partial plaster partitions were extended to the ceiling by placing glass panels one foot in height on top of the existing 8'0" high plaster partitions. Sound pressure level readings were recorded and sound contours were plotted. (See Plate XXXI)

The room was sectioned off in three foot squares in height, length and width, and intersections are represented by numbers. (See Figure 3.7 Plate XXIX) The sections contained in the main test are shown. A sound consisting of random noise of pressure level of 100 decibels on the C - scale was emitted from a point source located where indicated on the plan. The doors to all the spaces in the office were closed during all stages of testing.

Observation

The four stages of the test showed the effects of the various acoustical treatments. Generally the sound pressure levels decreased from stage one to stage two by an amount that varied from six to nine decibels. This clearly showed that reducing the ceiling height and using more absorbing surface makes a room less reverberant and reduces sound levels. The difference in recorded sound pressure levels between the first two stages of the test, established that from both an objective view, and a subjective response there was a change, although

PLATE XXVIII

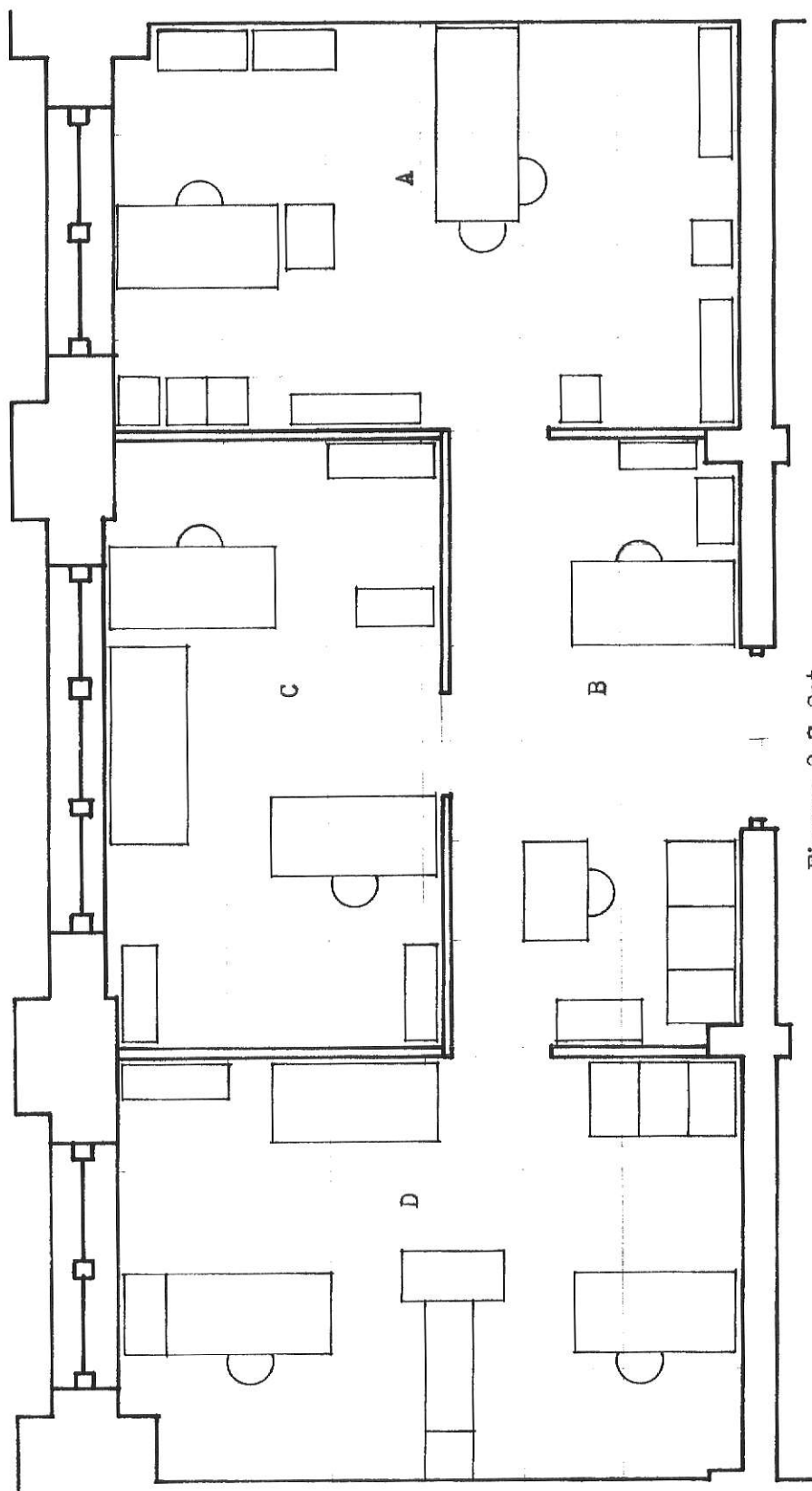


Figure 3.7 Set

PLANNING OFFICE DEPARTMENT PLAN

The Existing Furniture and Grid Used to Conduct the Tests.

Scale: $\frac{1}{8}" = 1'0"$

PLATE XXIX

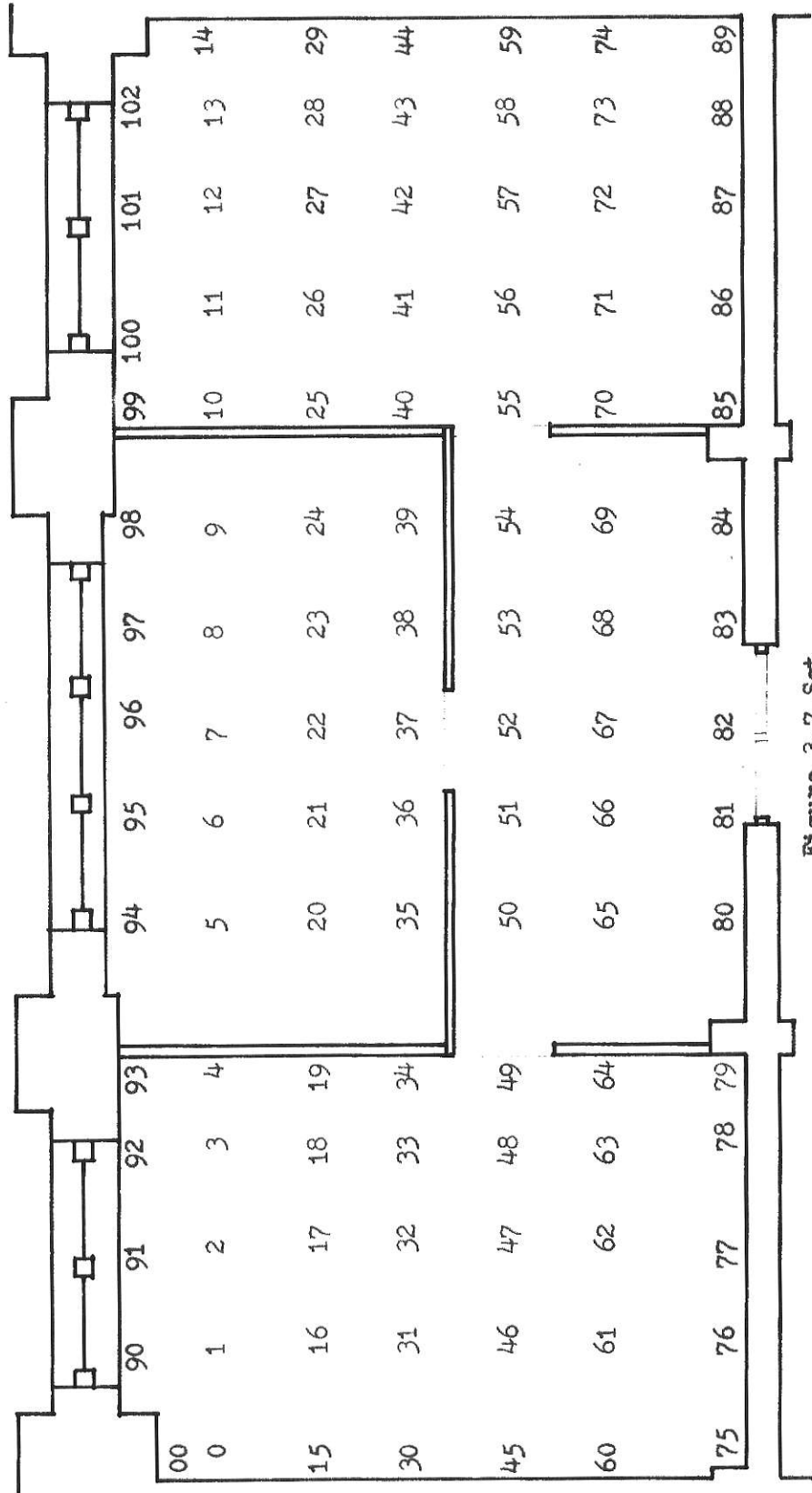


Figure 3.7 Set

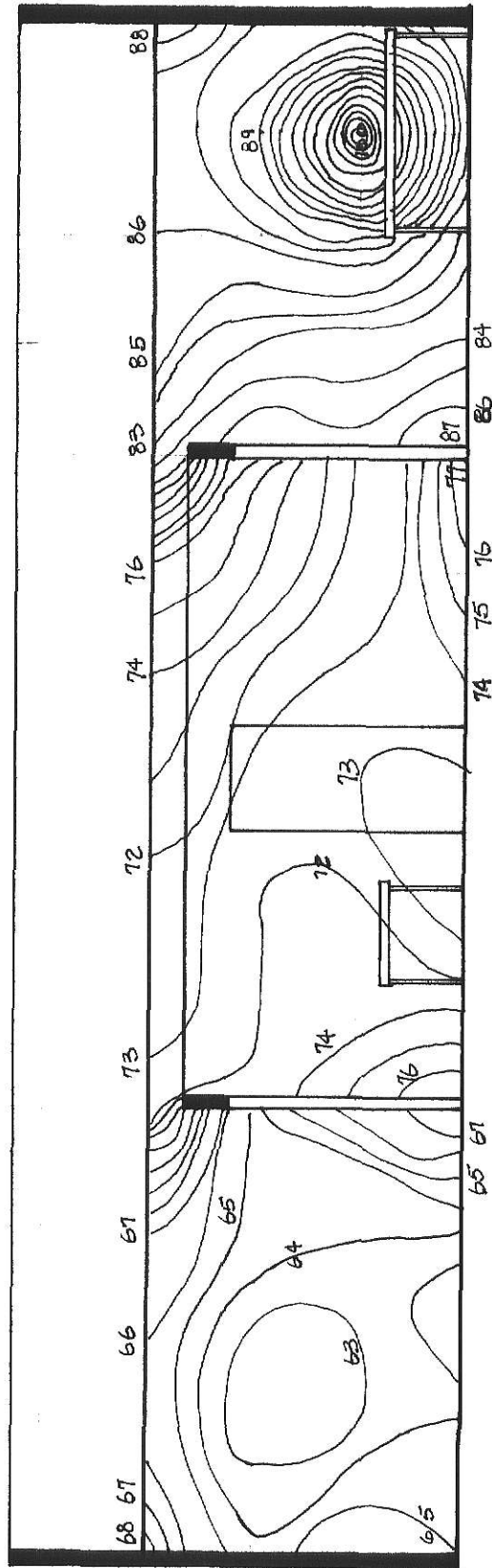
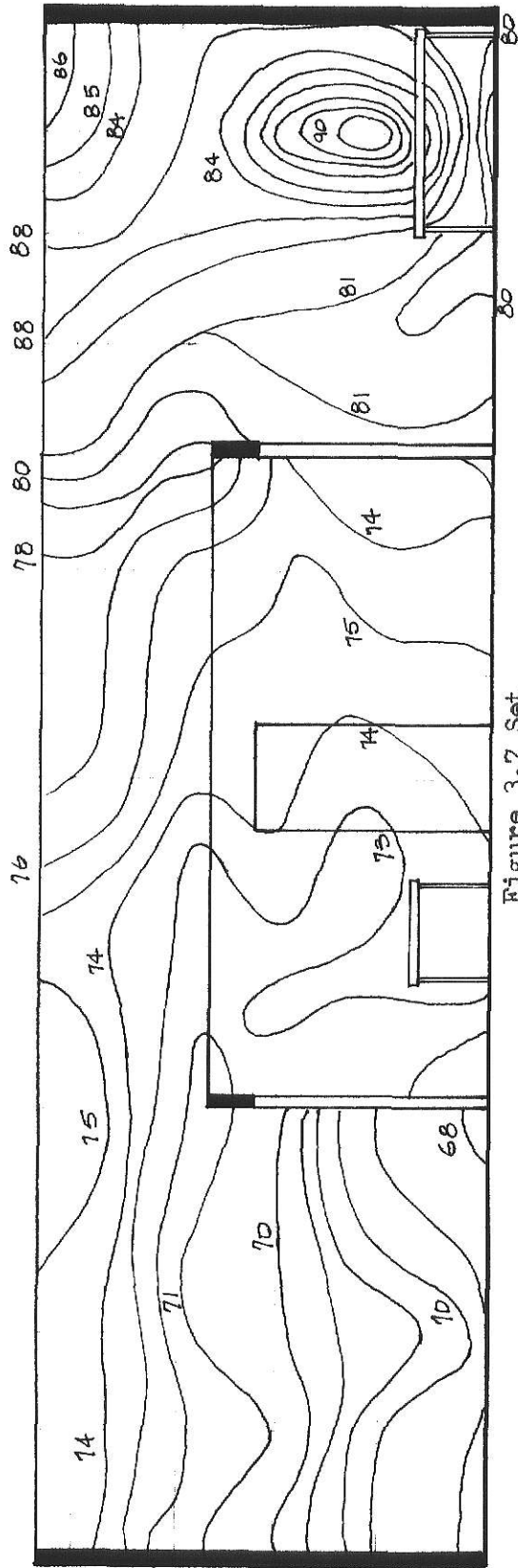
Scale: $\frac{1}{8}" = 1'0"$ Numerical Identification of Intersections of Grid Used in Test III

minimal, in the acoustical quality of the space. As was noted by employee opinion, the difference could be detected, and the room was quieter.

After the addition of the carpet on the floor in the third stage the sound pressure level dropped by the amount of one to four decibels below the stage two readings. This difference was not enough to substantiate a noticeable change in the sound level in the room. The absorption coefficient of the type and quality of the carpet used must have been too low to affect the overall room absorption and thus had little effect on the resultant sound pressure level. The coefficient of absorption for carpet is affected by the pile weight and density of the carpet and the type of backing used on the carpet. The larger coefficients of absorption are associated with the heavier carpet pile weight and density and heavier padding. The carpet used had a minimal pile weight density and backing, and the results of the stage three test indicate such carpet to be of little acoustical value.

The patterns of the sound pressure contours display the ability of sound waves to diffract over the partial partitions and reflect off hard surfaces, such as the plaster walls. These diffracting characteristics are shown graphically in sections 45-59 at points over the partitions and near corners and walls respectively. The contours clearly indicate the detrimental effects of sound leaks under partitions and around and under doors. This leakage is caused by poor seals and joints of the meeting surfaces and can be best graphically observed in sections 45-59.

PLATE XXI



Scale: 1/8" = 1'0"

PLATE XXXI

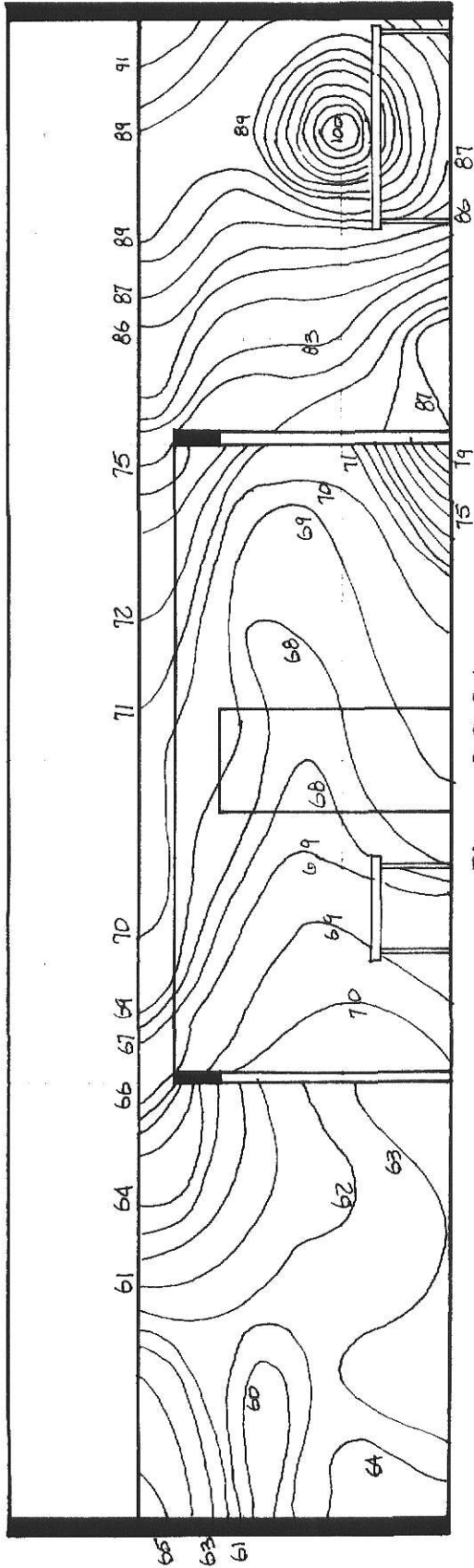


Figure 3.7 Set
Section 45-59 Test III

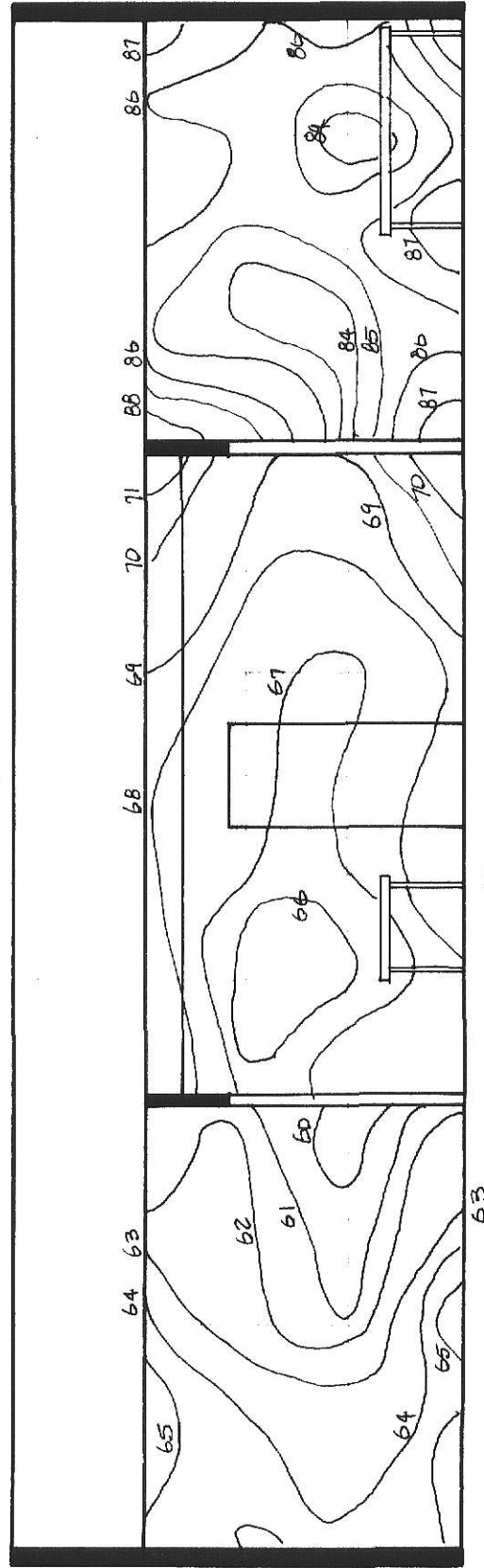


Figure 3.7 Set
Section 45-59 Test IV

Scale: 1/8" = 1'0"

In stage four a complete isolation is accomplished by the complete enclosure of each office space. The resultant attenuation in sound pressure level is shown clearly by the decrease in the number of contours. This is best seen in the cross sections of the room in this final stage, and the contour shapes. The sound pressure level has been decreased from 16 to 18 decibels between room "a," where the source is located and the adjacent room "b."

Conclusion

While final isolation of the rooms by extending all partitions to the ceiling yielded definite and substantially lower levels at the ceiling, the meter reading at desk level registered only 2-4 db. reduction. This would indicate that the closure had little effect. The observed statements of the office personnel, however, indicate a positive and significant reduction in sound loudness. This indicated a conflict of observation and a second test was conducted, analyzing the sound in the stage four rooms for octave band breakdown.

The octave analysis substantiated why the subjective response was greater than the measured change in sound level and indicated a need for more subjective measurements. All readings on the C - Scale tend to require further breakdown into octave analysis or measurement on the A - Scale. (This could not be done with the instruments available).

The general observation and conclusions to the four stages of alteration in this test can be summarized by the following statements:

1. The use of carpet alone did not substantially reduce the sound pressure level, but it aided the overall absorbing

quality of the space, represented in stage three, and would reduce the noise level in the space indirectly by buffering footsteps and other impact noise sources.

2. Point source sound waves pass from one space to the next by vibration carried through the partition, reflection off the ceiling and by diffraction over partial partitions. One of the best solutions for reducing this sound flow is to enclose each space fully from floor to ceiling with as little as one foot separation between the partition and the ceiling. The sound pressure clearly is sufficient to allow diffraction to occur over the partitions, thus materially raising the sound level on the other side.
3. Sound levels were clearly observed to increase as one approaches a vertical surface and were found to be highest in room corners. This would clearly seem to indicate that optimum furniture spacing and room arrangement would be such that all personnel seating positions should be located two or more feet from a vertical room divider or wall. (See Figure 3.8 Plate XXXII)
4. Repeated subjective observations established that the only stage to substantially change the audibility of conversations, occurred when the spaces were enclosed in the stage four change.

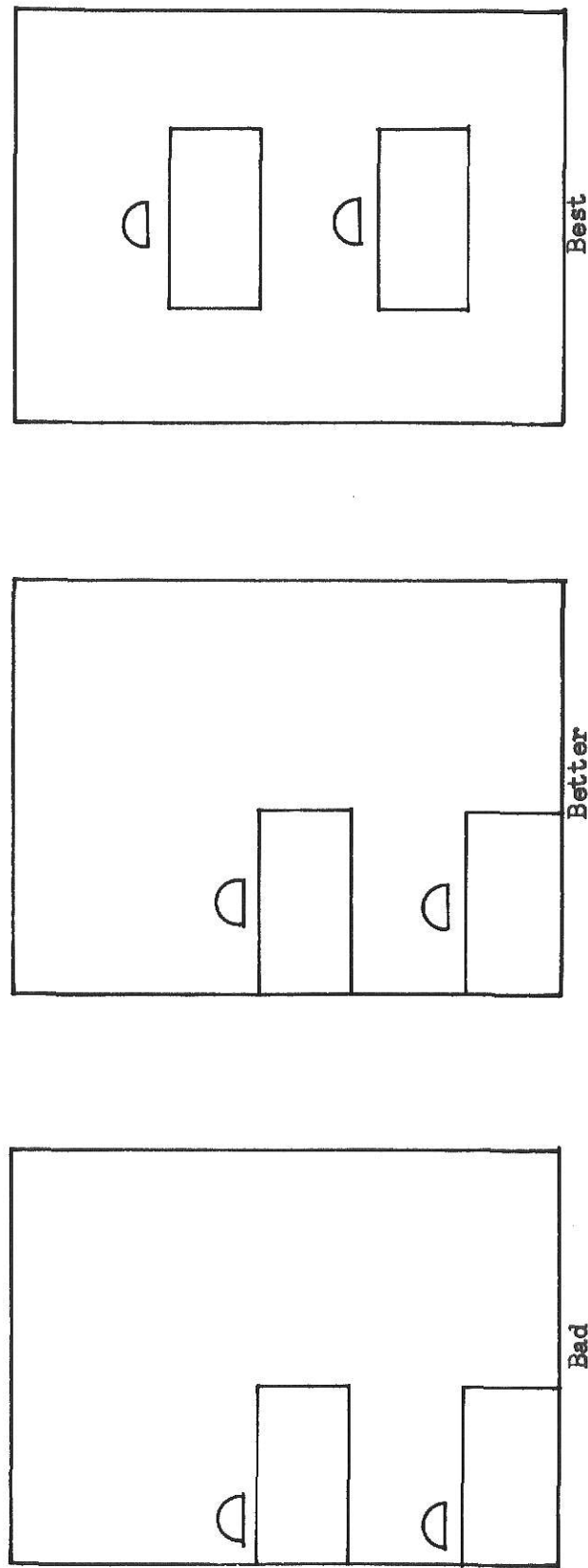


Figure 3.8

Varying Degrees of Furniture Placement
To Avoid Higher Sound Pressure Levels

The placement of furniture near walls, corners or vertical barriers should maintain a distance not less than two feet from these areas.

Scale: $\frac{3}{16}'' = 1'0''$

Test IV

OBSERVATIONS OF SPEECH ARTICULATION

Purpose

Speech audibility was tested in a large central public space of a bank which is a typical example of the application of current landscaping design trends. Articulative tests were carried out under exact conditions encountered in typical banking procedures. The opinions of a testing team as well as those of the bank's employees were recorded. Sound pressure levels were taken at various positions and these results recorded. These tests were conducted to establish what type of conditions are needed to affect the audibility of speech. The results were judged and evaluated on a basis of both quantitative and qualitative observations.

Technique and Equipment

A three man team with two sound level meters positioned themselves to measure sound level pressures at various locations in the bank. Readings of the meters were taken and opinions of the team members were recorded as to the audibility of the speech under certain conditions and over certain distances. Opinions of the employees were also recorded.

The central space of the bank was a large open space with a high ceiling. The flanking walls surfaces are wood panelling and vinyl covered plaster walls and the floor was carpeted. The teller area was an oblong shaped area in the center of the space. The tellers were

seated at counters that were approximately seven feet wide. Behind the tellers were stand-up work areas with five foot high supports. There was no separation between the tellers. The teller area was flanked by seating areas and secretarial work stations. Lower ceiling offices with open entrances were in recessed spaces adjacent to their respective secretarial work areas.

Observation

When the number of people doing business at teller stations was at a minimum the general background sound pressure level throughout the banking space was approximately 45 dbA.

When a typist used a typewriter the level in the immediate vicinity was raised to a point approaching from 50-65 dbA varying with observer locations stationed from 15-30 feet from the noise source.

With two people conversing at positions as shown in Figure 3.9 Plate XXXIII and while the background level was 45 dbA, conversation between two parties at point A could be clearly understood by a listener at point B. When two parties holding a conversation moved to new seating location as shown in Figure 3.10 Plate XXXIII speech could not be understood.

In the vice president's office, Figure 3.9 Plate XXXIII, the general sound level was 50 dbA. The positioning of his desk in a direct line with the noise generated by his secretary's typing enabled the sound of the typewriter to be a distracting influence when our team was conversing in the vice president's office. The conversation occurring in the area of the vice president's secretary could be understood

PLATE XXXIII

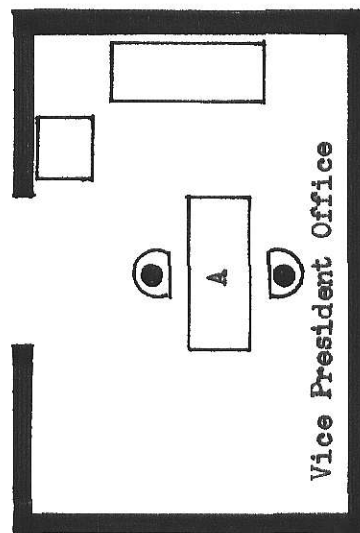
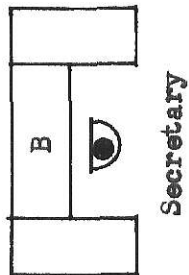
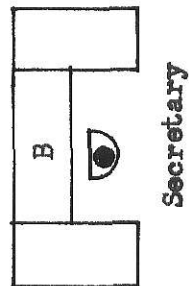


Figure 3.9

Observation of Lack of Speech Privacy
(with people in positions above)

Scale: $\frac{1}{8}" = 1'0"$

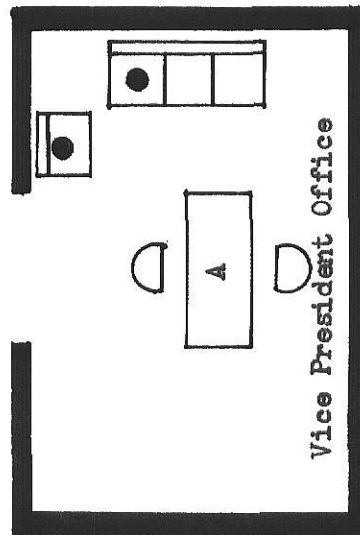


Figure 3.10

Observation of Speech Privacy
(with people in positions above)

while the overall background noise level in the bank was minimum. As intermittent noise from typewriters, telephones and conversations occurred in the bank, the ability to understand the speech coming from this secretary's work area decreased.

In the large central space a team member was seated in the number two position in the seating area and could understand the conversation flanking him at position number one. (See Figure 3.11 Plate XXXIV) This situation depended upon the relative loudness of the speaker's voice. The degree of loudness of the speaker's voice in turn depended directly upon the amount and type of background noise. The louder and more intermittent the background noise, the louder the speaker would have to speak to be understood.

Conclusion

The clear conclusion from all observations taken in the bank area indicated that despite the use of carpeting, acoustical tile ceiling and generous spacing of employee desk positions, speech could be clearly heard over a great distance. Furthermore, speech privacy was achieved only at times when there was present a distracting masking sound of higher than normal level in the immediate area of the listener.

**THIS BOOK
CONTAINS
NUMEROUS PAGES
THAT WERE
BOUND WITHOUT
PAGE NUMBERS.**

**THIS IS AS
RECEIVED FROM
CUSTOMER.**

OBSERVATIONS FOR PLATE XXXIV

When the observer was in position '2' the sound level from only secretary 'B' typing was measured to be 52 dbA. When only secretary 'A' was typing the sound level at position '2' was measured to be 60 dbA. The change in sound pressure levels was due to the difference in the position of secretary 'A' and 'B.' A higher reading was obtained from the 'A' secretary's source because when she typed she faced position '2' and secretary 'B' typed with her back to position '2.'

A sound pressure level at position '3' was measured at position '1' to be 53 dbA with the teller at position '3' speaking and only 45 dbA without the teller speaking. At position '4' a sound pressure level of the conversation between the persons at position '1' and '3' was about 50-54 dbA and with typing in the background 56-58 dbA. When the sound level meter was moved to position '5' the sound pressure level was 50-52 dbA and with typing it was 53-54 dbA. When in positions '4' and '5' the conversations could barely be heard.

PLATE XXXIV

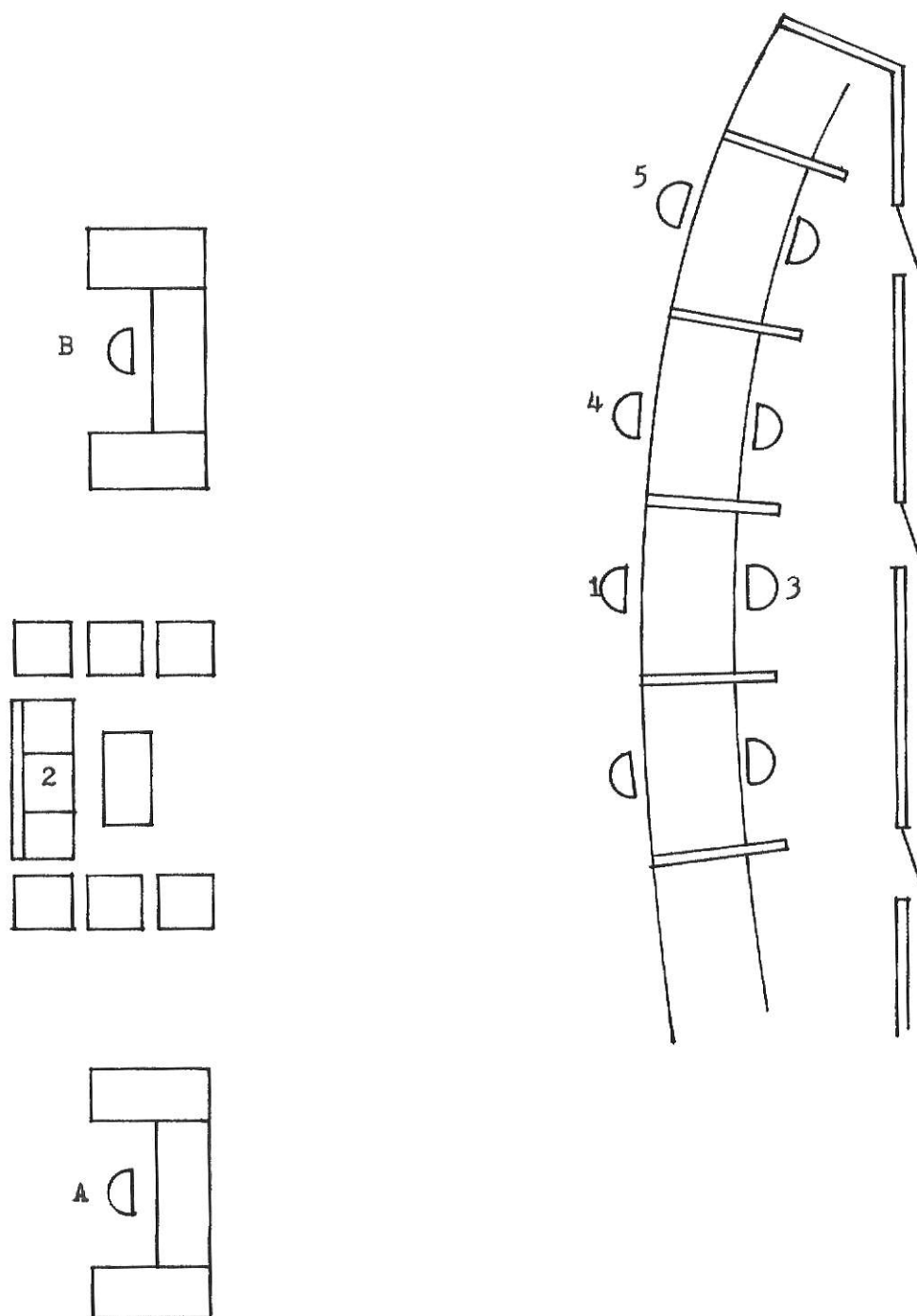


Figure 3.11

Observations of Speech Articulation in a Landscaped Bank
 Scale: $1/8'' = 1'0''$

Conclusion

From the four tests undertaken, an understanding can be developed in the requirements necessary for more technical testing procedures necessary to produce an office landscape partition or screen that will sufficiently attenuate sound so that speech privacy, acoustical isolation, and the proper sound conditions can exist for work concentration.

The results of the first report gave some theoretical shapes for a partition with the acoustical qualities mentioned above. The subsequent two reports used this as a basis to actually measure values of the characteristics of sound waves to determine the resulting form in the first report. From these quantitative reports reinforcing evidence substantiated the characteristics of sound wave motions and also the effects of various sound absorbing or reducing treatments. The fourth report gave objective evidence to existing knowledge on the conditions that affect speech articulation.

The assimilation of this research reveals the qualities necessary for maximum noise control in a landscaped office space, and provides a theoretical form and the character of the partial partition used to attenuate intermittent noise from work areas.

The means for correcting the general background noise level in a landscaped office is to create a "synthetic free field" by using highly absorbing surface throughout the office space. Examples are:

1. Use carpet of heavy pile density and thickness, backed with jute, Kraft cord or other type of stuffer as an underlay of heavy weight on the floors.

2. Wall surfaces can be also treated with a highly absorbent material such as cork or carpet, giving these surfaces a decorative and textured effect. To obtain a good absorption at low-frequency, however, carpet should either be furred out from the wall to secure the required air space for increased absorption or be backed by a porous material like polyurethane, rockwool or fiberglass.
3. Suspended ceiling material used should be of the highest absorption quality and the plenum space above the ceiling should be controlled by either application of absorbent material to its surfaces or suspension of an absorbent barrier within the space to produce adequate ceiling attenuation. This is done to prevent absorbed sound waves from being reflected back into adjacent spaces by the plenum. The surface of the ceiling should be of rough texture and porous and to further increase absorption and reduce reflectivity, can be irregularly shaped. Walls should run up to the underside of floor slabs above.
4. Joints around doors and windows should be sealed well to prevent leakage of sound energy. Doors which should be used have transmission losses equivalent to adjacent walls. Double or triple pane windows with air spaces between the panes should be used to reduce transmission of sound through them. Draperies can also be added to improve noise reduction and absorption

near glass surfaces. With the creation of a "synthetic free field" condition, the overall reverberation time and the general sound level is reduced. These basic characteristics were of minimum effectiveness in the stage three research, but evidence of the positive effects of using absorbing surfaces was shown and A - scale readings substantiated that good reductions in levels were achieved in the mid-frequency range.

The mid-frequency range is the range in which hearing occurs for people. From the tests conducted in the existing office spaces (Test III) sound pressure level readings were taken on the C - scale and an overall frequency response was measured. From the octave band analysis (Figure 3.12 Plate XXXV) taken in the last stage of this test, a substantial decrease of the sound pressure level from the two one-third octave analysis lines in the mid-frequency range is revealed. These two lines represent readings taken in space 'a' and 'b' respectively during the fourth stage of testing. This substantiated the great difference in the meter readings and the actual responses of the office employees to the fourth stage. This will also disprove the claim that the carpet had little effect on the acoustical quality of the space. Further tests conducted should be measured on the A - scale for a more positive response to the human hearing level. Although the conditions of a "synthetic free field" cannot be fully achieved indoors in a landscaped office situation, the closer one approaches this

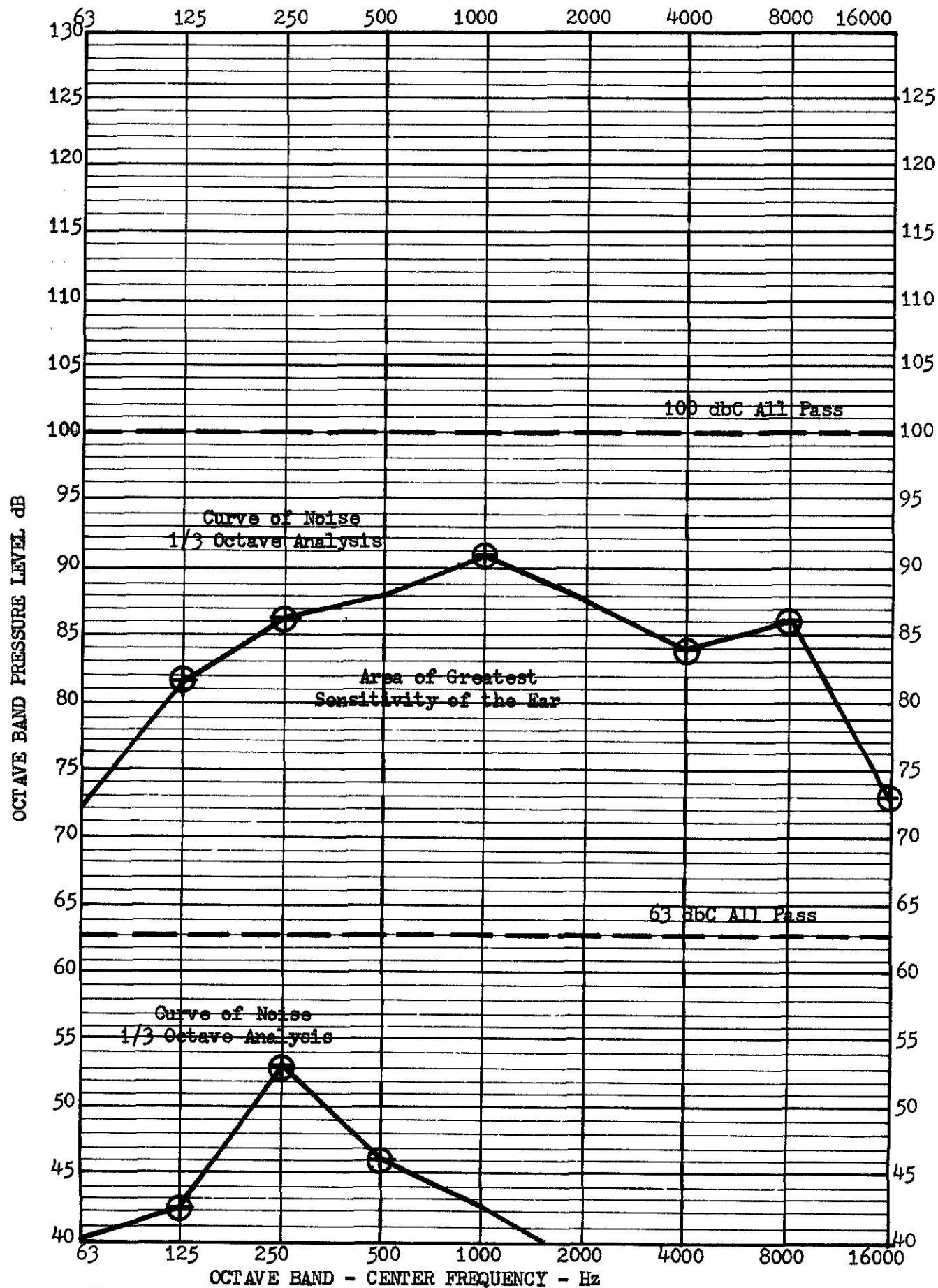


Figure 3.12

Flaming Office Fourth Stage

theoretical limit, the greater the reduction of sound pressure level in the space.

Basic characteristics of the sound flow patterns as the waves diffracted over partial partitions were displayed by testing in stages two and three. The diffraction of wave fronts passing over and around partitions is a vital characteristic of sound energy that one must consider if speech privacy is to be achieved, through the use of screens, dividers or partial partitions. The various shapes of theoretical barriers were tested to determine which shapes best prevent or alter the diffraction characteristics of sound waves and which best prevent them from reaching elevations that would interfere with the people working in the space.

Conclusions were made as to which shape best controlled these reflecting and diffracting waves. Sketches of forms of partial partitions utilizing these shapes are shown on Plates XXXVI and XXXVII. Further tests should be made on full sized replicas of these sketched partial partitions.

PLATE XXXVI

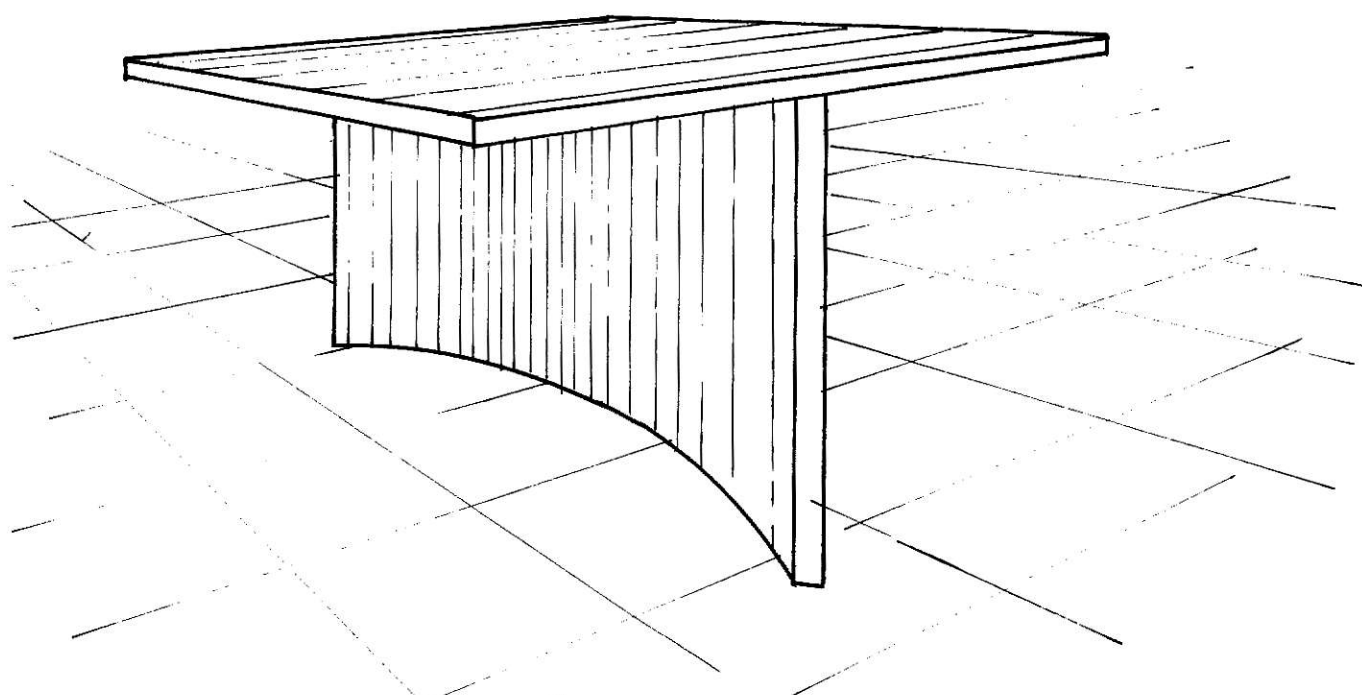
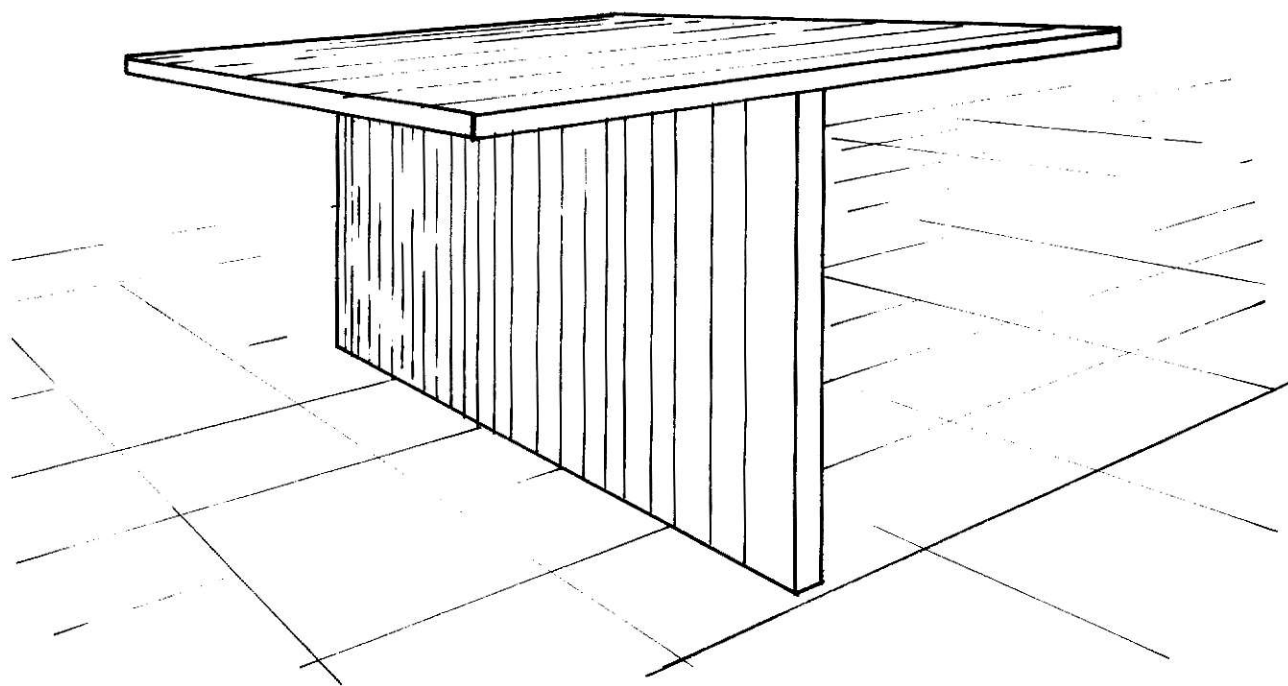


Figure 3.13
SUGGESTED FORMS FOR FURTHER STUDY

PLATE XXXVII

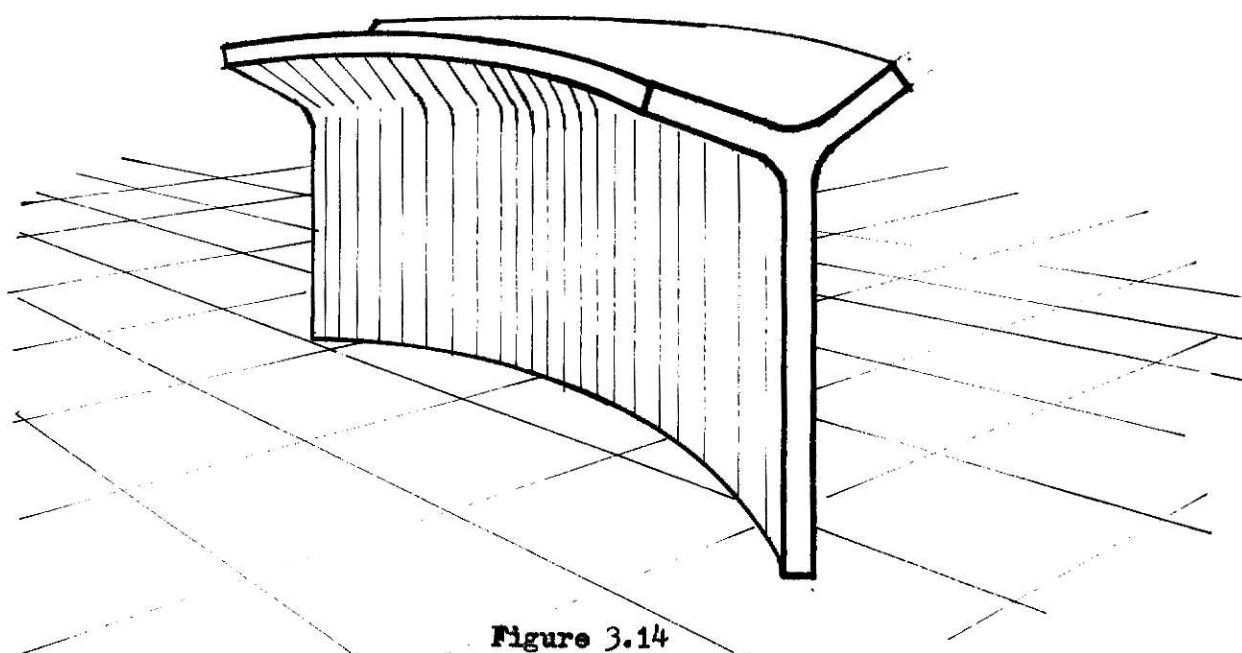
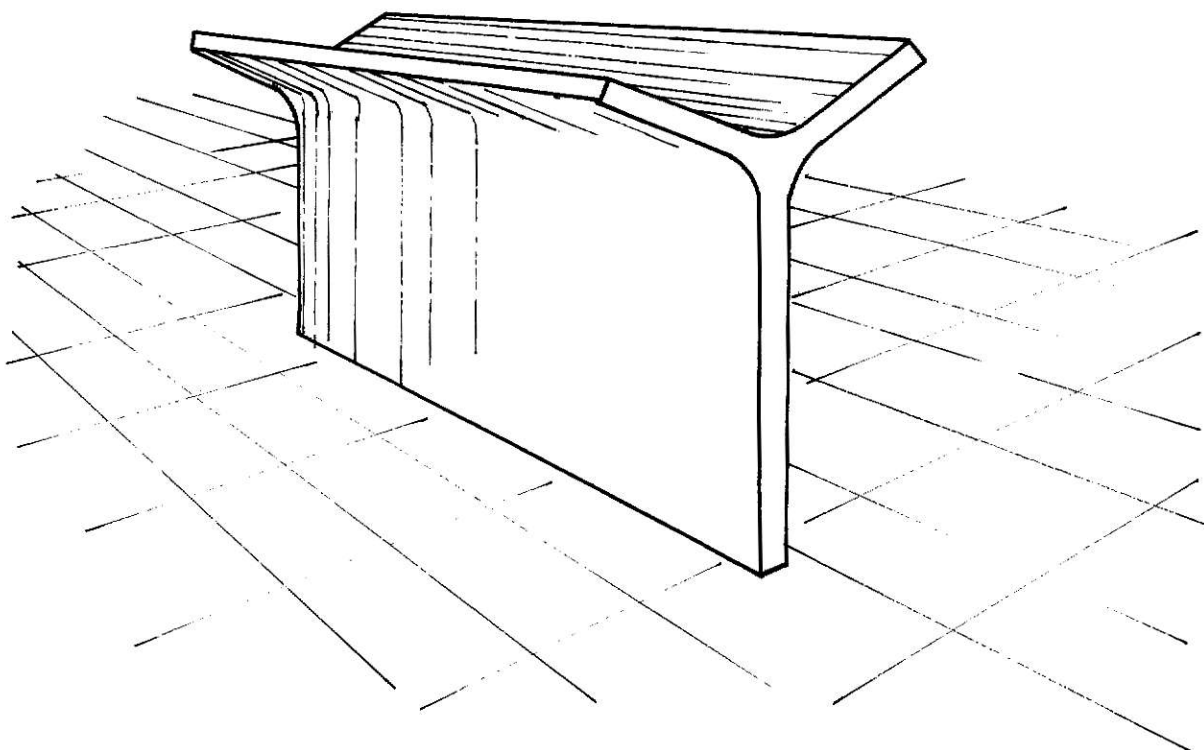


Figure 3.14

SUGGESTED FORMS FOR FURTHER STUDY

CHAPTER IV

GENERALIZATION PHASE

The four tests reported have theoretically described the sound wave patterns in relation to various shapes and sizes of partial partitions, taken a partial partition and tested it in a simulated landscape condition, shown the effects of changing partition conditions upon resulting acoustical measurements and subjective reactions, and subjectively studied the audibility of speech under actual office landscaping conditions. Although these tests rendered only preliminary knowledge of acoustical problems involving the flow of sound energy under typical office landscape conditions, they clearly establish the basis for further and more accurate testing and criteria for partition development.

This research provides direction toward the ultimate design and production of a partition or screen that will help reduce the noise level by refraction and reflection control between adjacent work areas and thus provide speech or work privacy in the office landscaped space.

From the ripple tank tests theoretical sound flow patterns were observed. Some of these appear to have a significant effect in altering the diffraction of sound waves from a point source on one side of a partition or screen to the occupied work space on the other side. Some of these ripple tank patterns were observed in the actual field tests using full scale partitions. All test results tend to substantiate the currently recognized criteria of a "synthetic free field" to be

in fact the overall condition of a typically landscaped office space.

It can be concluded from the four tests conducted that to establish the ceiling surface for a "synthetic free field" the ceiling should not be flat. With a flat ceiling, the ability of its absorbing material to fully utilize the absorbing qualities, by direct contact with the materials surface, is decreased. This is due to the nature of sound waves in an enclosure that strike the flat ceiling surface at grazing angles and therefore do not allow the maximum absorbing capacities for the ceiling material. To allow the ceiling material to utilize its absorbing qualities the shape of the ceiling should not be flat but irregular with material at greater angles to the sound wave flows. (See Figure 4.1 Plate XXXVIII)

It can be also concluded that the direction of sound sources have a great bearing on their intensity and effect. If a distracting sound generating source is in such a position that it is in direct line with the receiver without any barrier to interfere with it, it will cause a distraction. If this same distracting sound source was directed away or shielded from the receiver, it will then decrease in its intensity and also its ability to distract before it reaches the receiver. An example of this principle was viewed in the secretaries' positions 'A' and 'B' in the landscaped bank. The ability to screen or reflect sound waves away from possible receivers is another noise controlling quality for a "synthetic free field" conditioned landscaped office. A possible solution to this problem would be to design office furniture that house office machinery, as typewriters and adding machines, to

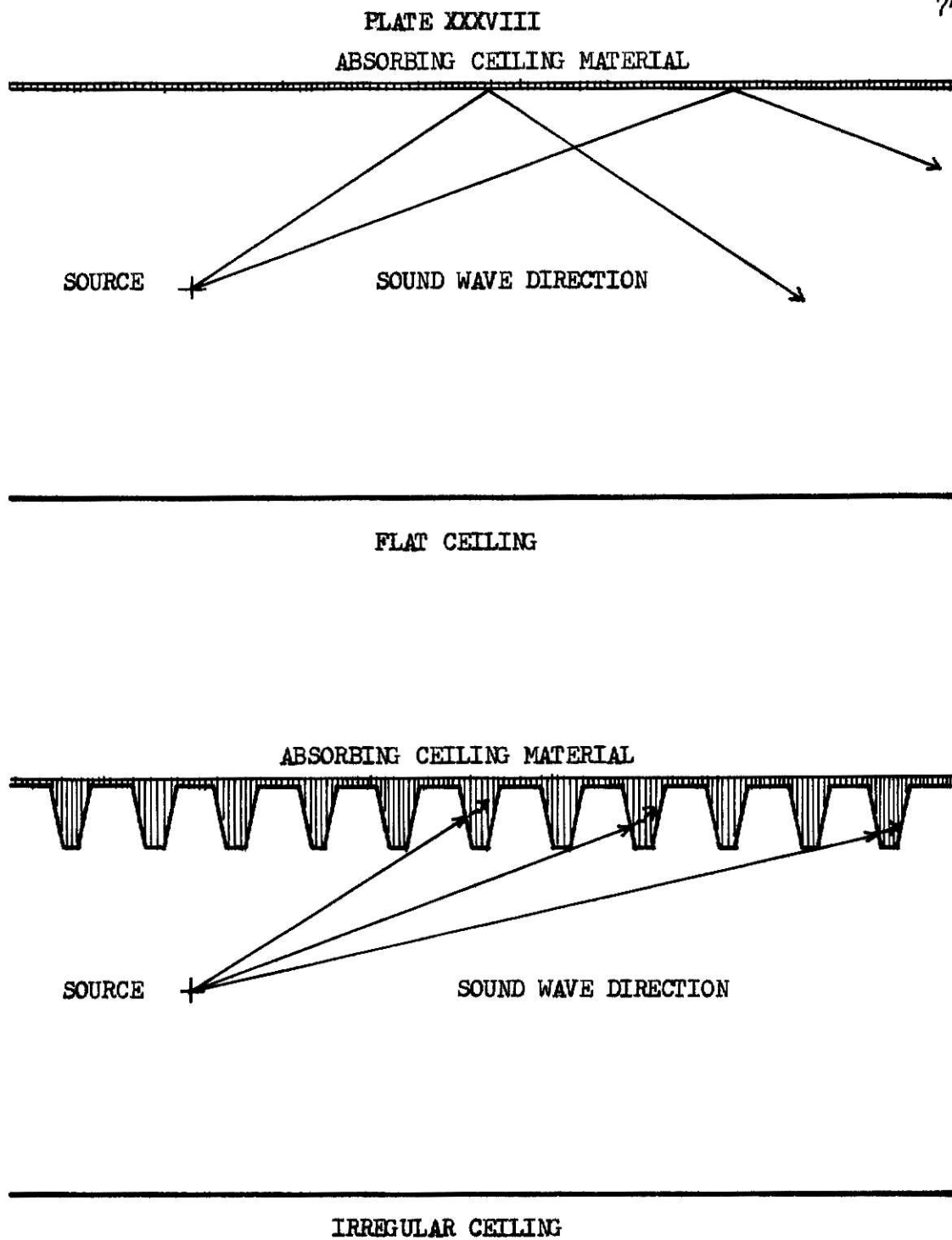


Figure 4.1

absorb and reflect sound waves from any adjacent work station and still allow maximum function and user comfort.

The next stage in the design development of a partial partition or screen for use in office landscaping would be to both quantitatively and subjectively test the suggested forms of the partial partition in a full scale "synthetic free field" condition. The materials used in the partition should be varied combinations of light weight absorbing and reflecting materials. These tests should be conducted so that many varied sizes, arrangements and business functions can be included.

Although this next stage of testing is primarily for acoustical qualities, the other requirements of structural support, aesthetic appearance, relationship to lighting, heating, ventilating and mechanical systems should be considered. Each of these functions should also be researched to determine its relationship to the office as a whole as well as to each other.

With the overall environmental effect being considered in the design of the office landscape partition the design requirements for this partition will be the desired results for a homogeneous system. The reason for this consideration is that an acoustical partition alone will not make the office landscape environment. If the acoustical qualities alone are considered they may create detrimental conditions to the lighting system by causing shadowing or glare, to the heating and air conditioning system by reducing proper air circulation, to the structural needs for functional work station support and to the total appearance of the office landscaped space.

An effective design for one element in the total system can be achieved only by considering, together, all the environmental elements that affect it in the design. Each individual system in the office landscaped environment should satisfy all functions required to enable all the necessary comfort factors for the workers in this environment, to establish an effective, efficient business operation.

This criteria can be achieved through continual use of subjective and objective analysis of all the environmental systems involved in the design of any one element of the environment.

CHAPTER V

SUMMARY

The basic concept of office landscaping is to plan an environment for the particular requirements and character of an organization taking into account what the organization is, what tasks are involved, how they are accomplished, and what the proper tools are to do the job; in every case, the goal is to achieve higher efficiency and worker comfort. The latter is of primary importance because if the staff is not comfortable and at ease, productivity will suffer.

One major discomfort factor in the landscaped office is unwanted sound or noise. Noise may obscure or reduce the clarity or quality of communication, reduce one's ability to concentrate, or it may produce other undesirable psychological effects. This situation results from the elimination of walls which, in the traditional office design, isolate noise.

All unwanted sound can be traced to two sources which are either internal or external noise. Reduction of external sources is possible through proper prior site selection and by locating the building at a distance as remote as possible from the traffic noise sources. Reduction of internal sources is possible through properly designed ventilating or heating and air conditioning systems, as well as office machinery, paying particular attention to the noise generating parts.

The last major internal source is people. The greater the number of people in a room, the noisier it is; however, the higher the background level, the louder an individual must speak in order to be heard above the noise.

Application of acoustical materials to walls, floors and ceilings will do little to reduce the noise source, but will help to reduce the general background sound level. Since the absorbative treatment tends to lower the background noise level, it allows individuals to speak more quietly and still be heard. Hence, the "people" noise level is reduced at its source.

When these alterations have been accomplished, the sources of prime contribution to the overall noise level of the space will have been reduced as much as possible and the area would then approach a theoretical "free field" condition. This condition is concerned only with the direct sound energy from the source; all other sound dissipates into the air as in an outdoor area free from any interfering objects. A theoretical "free field" can be approached indoors by reducing the overall reverberation time, which would reduce the sound level and, therefore, approximate what can be termed a "synthetic free field."

It has been discovered that using a synthetic free field, it is possible to understand speech at distances of as far as 17 feet from the source. Under this condition, speech privacy does not exist in large landscaped office spaces, because economical desk spacing is less than the maximum limit for articulation. To solve this problem, while not limiting or defeating the overall intent of the concept of

the landscaped office, partial partitions or screens must be used to reduce the sound levels.

By reducing a partition height and creating an opening between the ceiling and the top of such a screen, sound flow now becomes controlled by the flanking path and becomes a function of both reflection and diffraction, involving the open space above the partitions and its resultant airborne path.

Therefore, this research involves the development of a landscaped office partition which will control both the diffracting and reflecting sound waves from a point source as well as the reflecting of other waves in the area. The extent of the development was to determine theoretical shapes of partitions that in a further study can be built and tested in actual landscaped office conditions.

In order to determine proper criteria for the designing of acoustical shapes of landscaped office partitions and dividers, it was necessary to first determine characteristics of wave motions and how sound travels in a typical landscaped space. The tests conducted were: observations of waves systems using a ripple tank, measured tests of sound flow around a simple landscaped partition, measured tests of sound flow in an existing subdivided office during four stages of acoustical treatment and observations of speech articulation in a landscaped bank.

The results from the test reports gave some theoretical shapes for partial partitions that may sufficiently attenuate sound for speech privacy, actually measured values from testing various existing

conditions of the characteristics of sound waves. From these quantitative tests, reinforcing evidence substantiated the characteristics of sound wave motions and also the effects of absorbing or reducing treatments. The final report gave objective evidence to existing knowledge on the conditions that affect speech articulation.

From the ripple tank tests theoretical sound flow patterns were observed. Some of these appear to have a sufficient effect in altering the diffraction of sound waves from a point source on one side of a partition or screen to the occupied work space on the other side. Some of these ripple tank patterns were observed in the actual field tests using full scale partitions. All test results tend to substantiate the currently recognized criteria of a "synthetic free field" to be in fact the overall condition of a typically landscaped office space.

The next stage in the design development of a partial partition or screen for use in a landscaped office would be to both quantitatively and subjectively test the suggested forms of the partial partition in a full scale "synthetic free field" condition.

These tests should be conducted so that many varied materials, sizes, arrangements and business functions can be included. Although this next stage of testing is primarily for acoustical qualities, the other requirements of structure, aesthetics, lighting, heating, ventilating, and mechanical systems should be considered. Each of these functions should be researched to determine its relationship to the office as a whole as well as to each other.

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APPENDIX A

ACOUSTICAL TEST OF OFFICE SPACE

Test Number 1

Source @ 100 db.

POSITION	LEVEL 1				LEVEL 2				LEVEL 3				LEVEL 4				LEVEL 5			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
00				70				71				71				75				77
0				69				70				71				71				74
1				69				70				70				70				73
2								72				71				72				75
3				69				69				69				70				74
4							73	70			73	71							76	
5			72				72				73					72			76	
6							74				73					73			75	
7			72				73				73					74			76	
8							74				74					74			76	
9			73				72				74					75			77	
10											81					78			79	
11	78				79				79				70				80			
12	78				79				79				79				82			
13	79				80				79				79				81			
14					80				80				80				83			
15				70				70				70				70				74
16				69				70				70				71				74
17								70				70				71				75
18				69				70				70				72				75
19							73	70			75	70				70			76	
20			72				72				73					72			76	
21			72				72				73					73			76	
22			73				73				73					73			78	
23			73				73				74					74			77	
24			71				73				74					75			78	
25							73				80					79			80	

POSITION	LEVEL 1				LEVEL 2				LEVEL 3				LEVEL 4				LEVEL 5			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
26	78				78				79				80				81			
27	79				80				80				80				81			
28	80				80				81				80				82			
29					80				81				81				83			
30																				73
31																				73
32																				74
33				69				70				69				70				75
34				69				70				70				72				76
35			76				75				76				73				74	
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46				69				70								72				74
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52		74			73				74				73				76			
53		75			74				74				75				77			
54		75			75				75				75				67			
55	81	73			73				82				76				78			

POSITION	LEVEL 1				LEVEL 2				LEVEL 3				LEVEL 4				LEVEL 5			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
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57	80				82				82				83				83			
58	78				90				88				83				86			
59	80				82				83				83				85			
60			69					70								72			75	
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85	80				78				80							75				
86														82			85			
87														81			85			
88														80			84			

POSITION	LEVEL 1				LEVEL 2				LEVEL 3				LEVEL 4				LEVEL 5			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
89																	86			
90				69				72				73				73				76
91												72				72				75
92				71				70				70				72				75
93			73				75				73					72			76	
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97			75				74				73					73			77	
98			73				74				73					75			77	
99							79				79					79			80	
100	78				77				77								77			
101	80				79				78								78			
102	79				79				79								80			
																	81			

ACOUSTICAL TEST OF OFFICE SPACE

Test Number 2

Source @ 100 db.

POSITION	LEVEL 1				LEVEL 2				LEVEL 3				LEVEL 4			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
00				69				68				69				70
0				68				68				68				68
1				66				65				67				68
2				68				65				64				68
3				65				65				64				66
4				68			72	66				67			72	70
5			73				70					70			72	
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11	83				82				82				82			
12	82				82				82				82			
13	82				81				82				82			
14					85				83				84			
15				67				65				66				68
16				65				64				65				66
17				66				65				66				68
18				65				64				66				68
19			68				65					68				73
20			72				71					71			72	
21			72				71					70			72	
22			73				73					71			72	
23			71				72					72			72	
24							72					72			73	
25			74				71					72				
26	81				82				82				82			

POSITION	LEVEL 1				LEVEL 2				LEVEL 3				LEVEL 4			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
27	82				82				84				86			
28	82				83				83				84			
29	86				86				85				87			
30								66				67				68
31																
32																
33				66				64				65				68
34			77	66			73	64			64	65			71	
35		74				74	76			74	62			73		
36		76				75	73			73	71			71		
37		76	75			76	74			73	73			76		
38		75	73			74	73			73	73			75		
39		76	73			73	73			75	73			75		
40		86				85	78			85	77			84		
41	84				84				83				85			
42	84				85				84				86			
43	83				86				87				86			
44	84				86				86				88			
45				65				66				64				68
46				64				63				62				66
47				65				63				63				66
48				64				64				65				67
49		76		67		74		66				65				
50		72				70				72				73		
51		75				72				72				74		
52		73				72				72				72		
53		74				73				72				74		
54		76				77				75				76		
55	87	77			85	71			86	76			83	83		

<u>POSITION</u>	<u>LEVEL 1</u>				<u>LEVEL 2</u>				<u>LEVEL 3</u>				<u>LEVEL 4</u>			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
56	84				83				83				85			
57	83				88				86				86			
58	81				100				89				86			
59					87-				87+				88			
60				65				87				67				68
61				65				65				64				66
62				65				63				63				67
63				64				63				65				65
64												67				
65		74				71				71				70		
66		73				71				72				71		
67		72				71				70				72		
68		72				73				72				71		
69		74				70				72				74		
70						75				74				75		
71	82				80								83			
72	83				82								84			
73	83				84								86			
74	85				84								86			
75								67					87			
76								66								70
77								67								67
78								65								68
79																67
80																
81		76				75				72				74		
82		74				73				73				72		
83						74				73				74		
84						73				72				71		
85	82				80					71				74		
86									81				85			
87	83				84				85				86			

<u>POSITION</u>	<u>LEVEL 1</u>				<u>LEVEL 2</u>				<u>LEVEL 3</u>				<u>LEVEL 4</u>			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
88																
89	85				85				85				88			
90				66				67				70				69
91								69				69				70
92				68				69				67				67
93			73				73	69				72			72	72
94			72				72	70				70			71	
95			71				69					69			72	
96			72				72					69			73	
97			73				70					70			73	
98			71				73					70			72	
99	85				83		77					75				
100	84				83				83				83			
101					83				80				82			
102					80				80				83			
									80				81			

ACOUSTICAL TEST OF OFFICE SPACE

Test Number 3

Source @ 100 db.

POSITION	LEVEL 1				LEVEL 2				LEVEL 3				LEVEL 4			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
00				63				65				68				70
0				65				66				68				67
1				62				61				61				64
2								62				61				63
3				63				63				63				66
4			69				68	64			68	64	69			67
5			66				66				64		66			
6			65				64				64		68			
7			66				65				65		69			
8							68				67		68			
9			67				65				66		70			
10			70				69		84		69		71			
11	84				81				82				86			
12					83				85				85			
13	85				83				84				85			
14									87				88			
15				63				64				64				66
16				63				62				62				63
17								61				61				64
18				62				63				62				65
19			70				66	66			67	65			69	67
20							68				67				66	
21							67				66				67	
22			67				68				64				68	
23			69				67				67				69	
24			67				66				66				70	
25			72				71				70				74	
26	84				82				83				88			86

POSITION	LEVEL 1				LEVEL 2				LEVEL 3				LEVEL 4			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
27									86				87			
28	85				85				85				86			
29									87				89			
30															67	
31															63	
32															64	
33				64				63				61			63	
34		70		66		69		66		70	70	63		72	71	66
35		70	71			68	70			69	69			71	68	
36		72				69	68			70	68			70	68	
37		70	70			69	68			69	68			72	70	
38		72	72			72	70			72	69			74	70	
39		75	70			73	68			74	69			75	72	
40	87	82			86	75			88	73	72		88	78	78	
41	84				82				83				86			
42	86				87				86				89			
43	86				89				88				87			
44	86				87				88				91			
45				64				65				60				66
46				62				63				60				65
47				63				63				62				61
48				63				62				61				64
49		70		64		71		63		70		61		71		65
50		69				68				67				70		
51		69				68				68				70		
52		69				68				69				70		
53		70				69				68				71		
54		71				69				69				72		
55	88	80			87	71			86	71			88	75		
56	89				83				83				86			

<u>POSITION</u>	<u>LEVEL 1</u>				<u>LEVEL 2</u>				<u>LEVEL 3</u>				<u>LEVEL 4</u>			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
57	86				87				87				89			
58					104				89				89			
59					89				89				92			
60				64				64				65				66
61								60				62				63
62								63				61				64
63				63				61				62				63
64												65				66
65		71				67				68				70		
66						68				68				66		
67		67				66				66				67		
68						68				69				70		
69		68				66				68				70		
70										70				74		
71	84				82				83				86			
72	83				84				86				88			
73	86				86				87				86			
74	88				87				87				89			
75								63				65				68
76				66				63				64				66
77								63				63				65
78				64				64								65
79																
80																
81		70				70				68				72		
82		72				70				68				71		
83		71				69				68				72		
84						70				69				72		
85	83				82					70				72		
86									83	69				74		
87					85				87				86			
88													87			
													89			
													88			

POSITION	LEVEL 1				LEVEL 2				LEVEL 3				LEVEL 4			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
89													91			
90								66				66				68
91								66				65				67
92				65				64				63				65
93							71	65			70	66			77	68
94				67				68				65				70
95							65				66					
96							67				74					
97							68				68					
98			68				69				67					
99	86		76		86		72		84		71		89			
100									82				83			
101					84				84				87			
102	86				83				83				84			

ACOUSTICAL TEST OF OFFICE SPACE

Test Number 4

Source @ 100 db.

POSITION	LEVEL 1				LEVEL 2				LEVEL 3				LEVEL 4			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
00				64				65				66				66
0				64				65				64				64
1				61				63				62				63
2				62				63				62				63
3				63				61				65				64
4			65				65	64			65	65			66	63
5			65				64				64				64	
6			65				64				64				65	
7			65				64				64				66	
8			64				65				64				65	
9			65				65				65				66	
10			69				67				67				68	
11	83				81				82				85			
12	81				82				82				83			
13	80				81				84				84			
14					83				83				86			
15				62				61				61				63
16				64				63				60				62
17				63				61				62				62
18				63				66				61				62
19			66				64	62				66			66	63
20			64				64					63			65	
21							65					65			65	
22			65				64					63			65	
23			64				64					63			66	
24			66				65					64			68	
25			70				70					63			69	
26	85				80				82				86			
													82			

POSITION	LEVEL 1				LEVEL 2				LEVEL 3				LEVEL 4			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
27	83				83				82				84			
28	84				85				85				85			
29					84				84							
30																63
31																69
32																67
33				61				60				60				60
34		70		60		68	68	65		69	68	60		70	69	63
35		70	69			66	67			68	69			69	68	
36		70				70	67			68	67			70	68	
37		70	67			68	67			68	67			70	68	
38		70				69	67			69	68			71	69	
39		72	69			71	68			70	68			72	69	
40	87	74			83	71	70		86	70	69		86	74	72	
41	86				83				83				84			
42	88				87				84				84			
43	90				90				86				86			
44									86				87			
45				63				64				63				64
46				63				64				64				65
47				66				61				62				64
48				63				61				62				62
49		68		62				60				61				63
50		68				66								69		
51		69				67				66				68		
52		68				68				67				68		
53		68				67				67				68		
54		70				68				68				70		
55	88	72			84	69			87	69			88	72		
56	85				84				84				85			
57	88				86				85				86			
58	86				89				86				85			

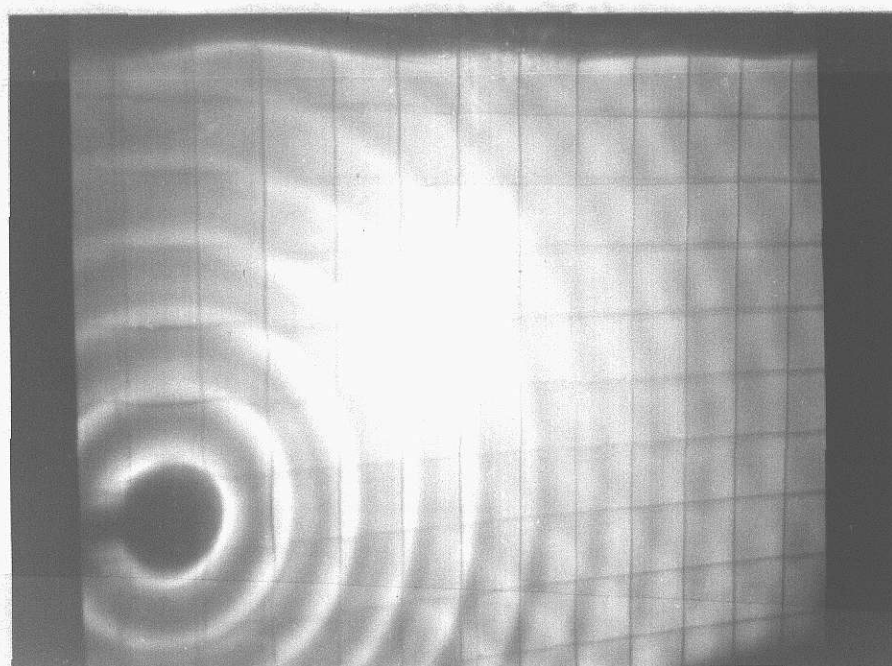
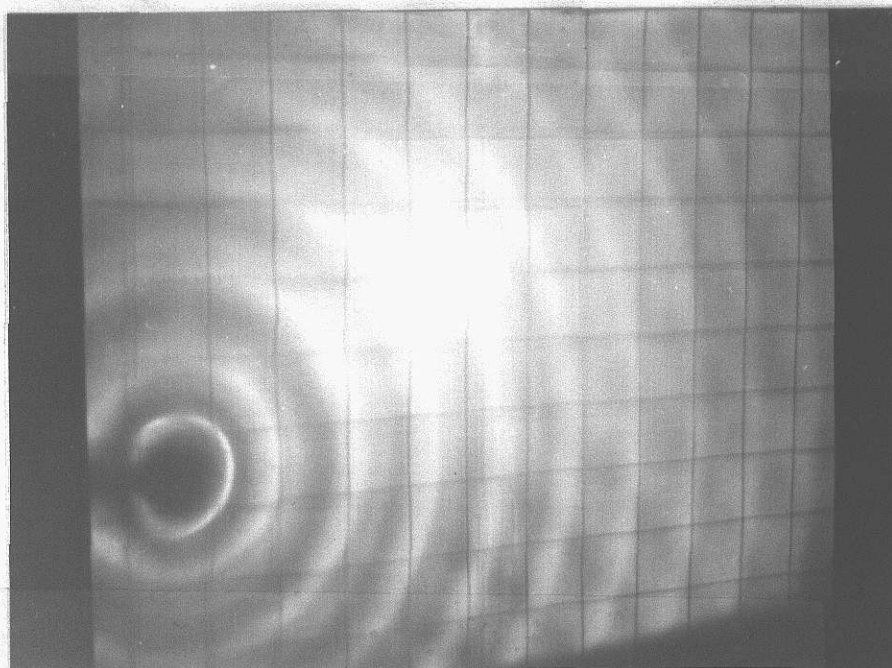
POSITION	LEVEL 1				LEVEL 2				LEVEL 3				LEVEL 4			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
59	89				85				86				88			
60				64				62				62				63
61								60				61				64
62				62				64				61				63
63				64				63				64				64
64		68				68				68		66		69		67
65		66				67				66				68		
66										67				68		
67						68				66				66		
68		67				68				66				68		
69		67				68				66				69		
70		68				69				66				71		
71	84				78				83				87			
72	84				84				83				84			
73	86				84				84				85			
74	88				81				85				87			
75				65				62				63				67
76				62				61				62				64
77				62				62				62				64
78				62				63				62				64
79																68
80														70		
81		69				68				70				70		
82		69				68				67				68		
83		70				69				69				70		
84						69				68				69		
85	86															
86	84															
87	86				83				86				88			
88	86				83				84				85			

<u>POSITION</u>	<u>LEVEL 1</u>				<u>LEVEL 2</u>				<u>LEVEL 3</u>				<u>LEVEL 4</u>			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
89	86				84				89				89			
90				64				63				64				65
91				64				62				63				67
92				64				65				63				69
93				64				66				65			69	66
94			64				64					68			69	
95							64					64			66	
96							65					64			67	
97							65					65			64	
98			69				66					66			67	
99			72				70					70			69	
100	83				82				83				87		73	
101	81				83				78				80			
102	82				80				82				82			

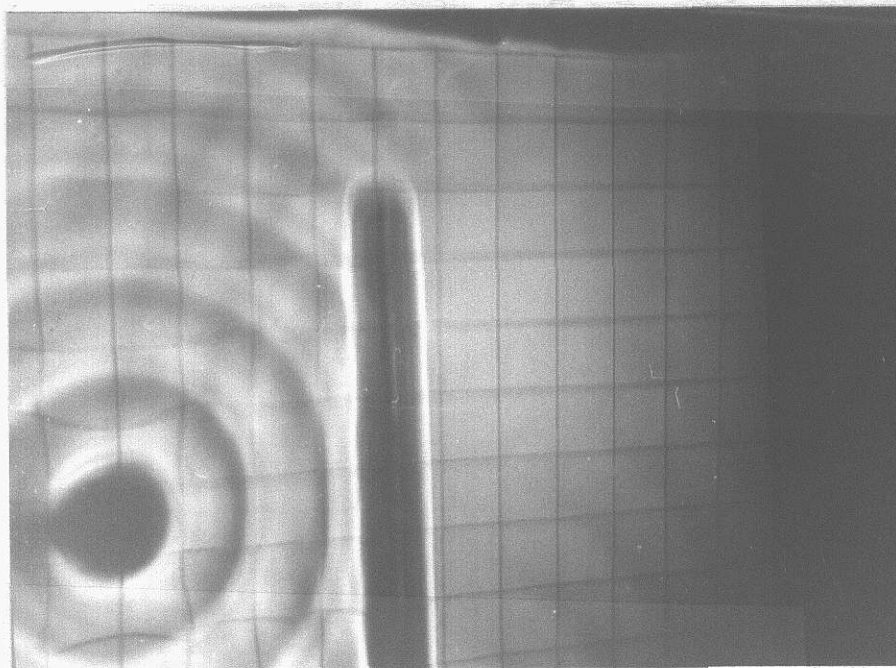
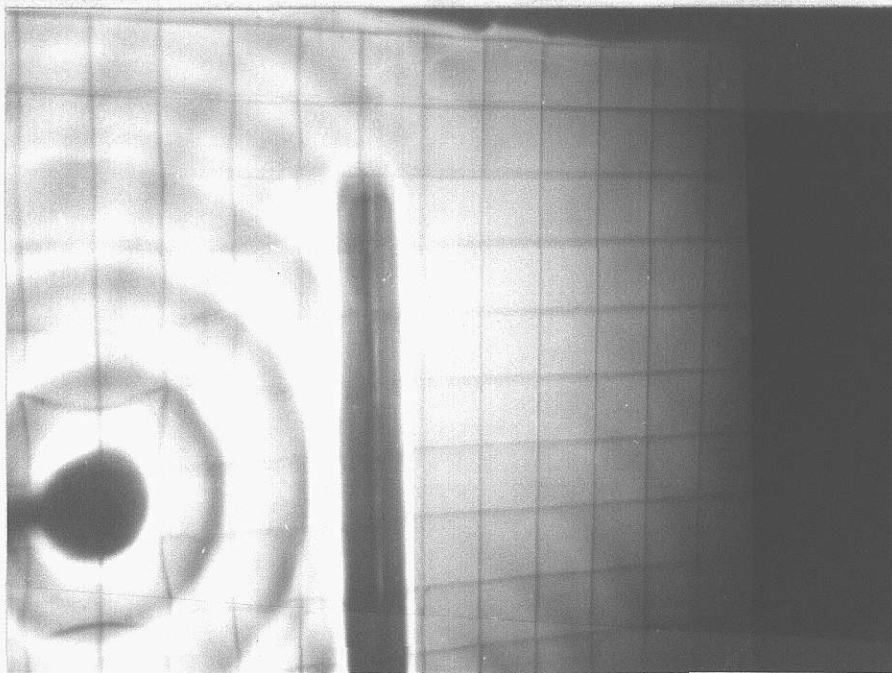
APPENDIX B

**THIS BOOK
CONTAINS
NUMEROUS
PICTURES THAT
ARE ATTACHED
TO DOCUMENTS
CROOKED.**

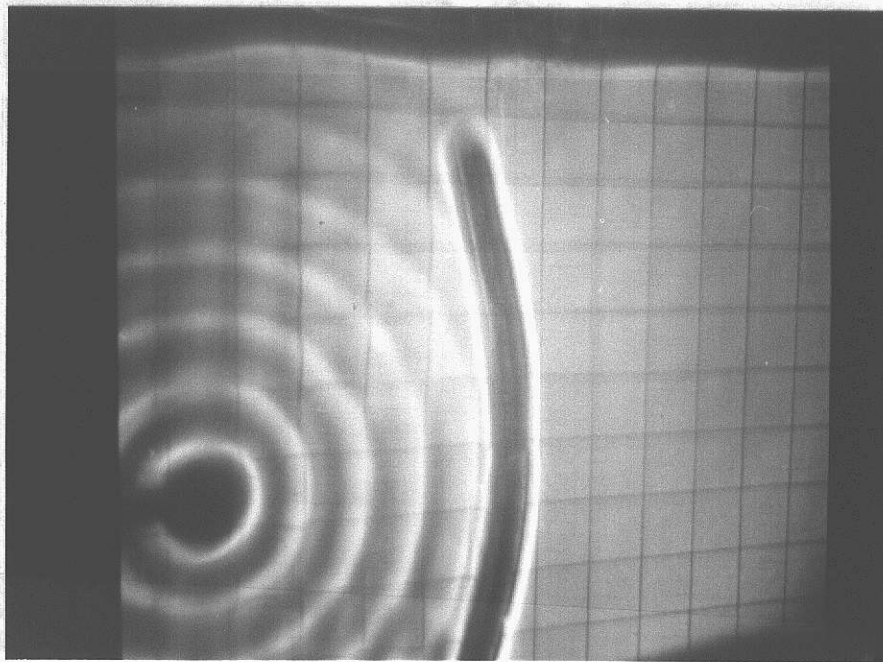
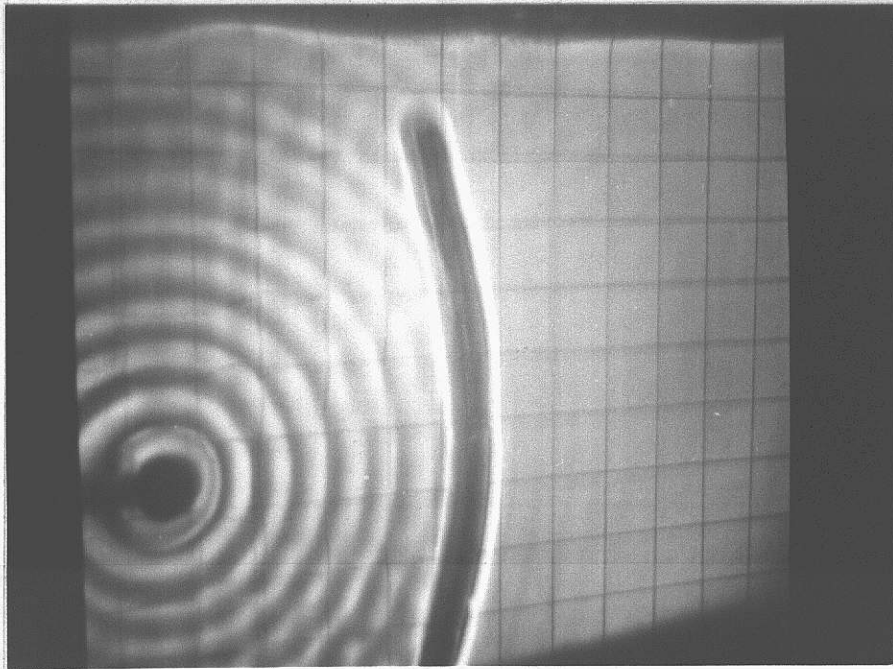
**THIS IS AS
RECEIVED FROM
CUSTOMER.**



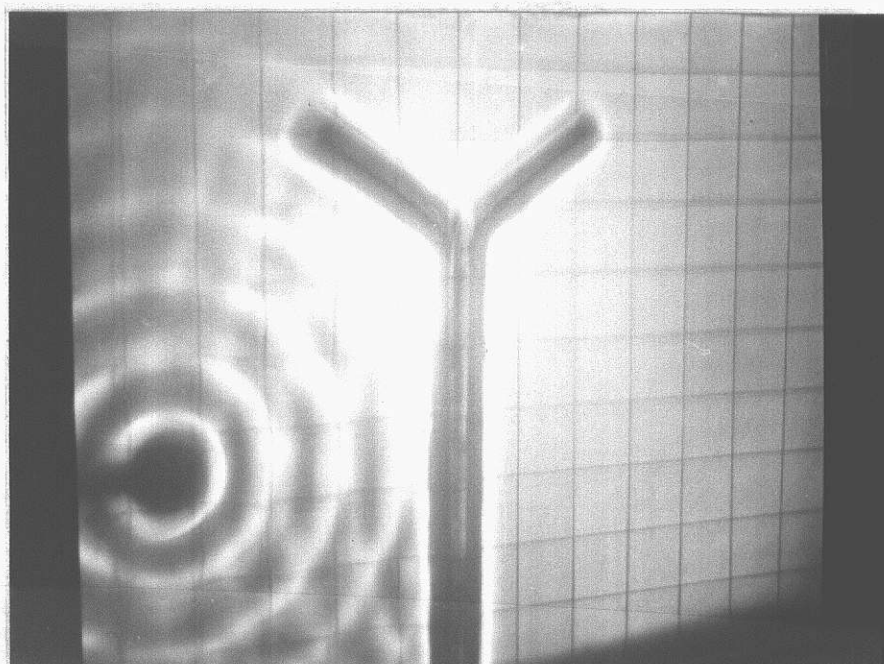
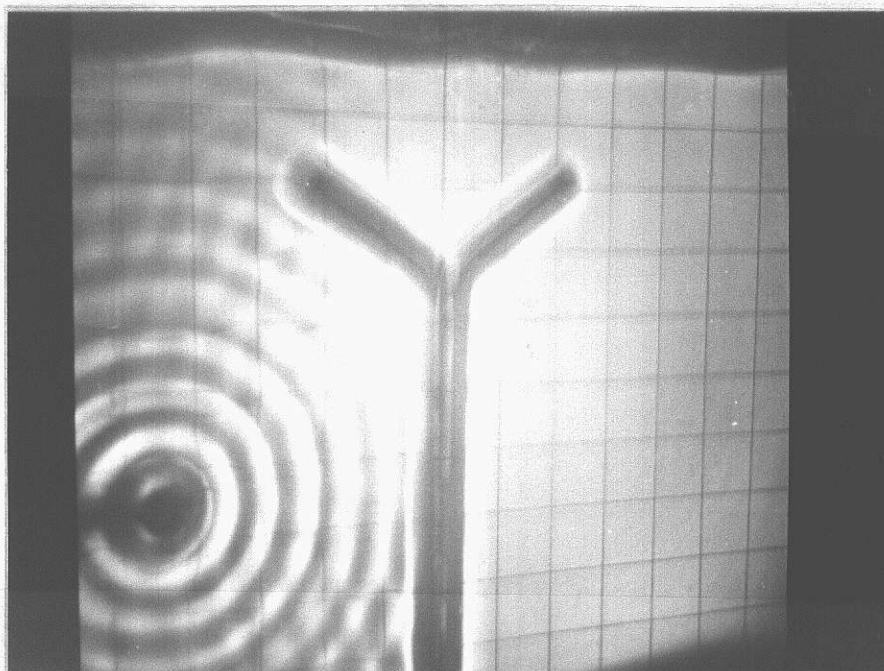
PHOTOGRAPHS OF RIPPLE TANK TESTS



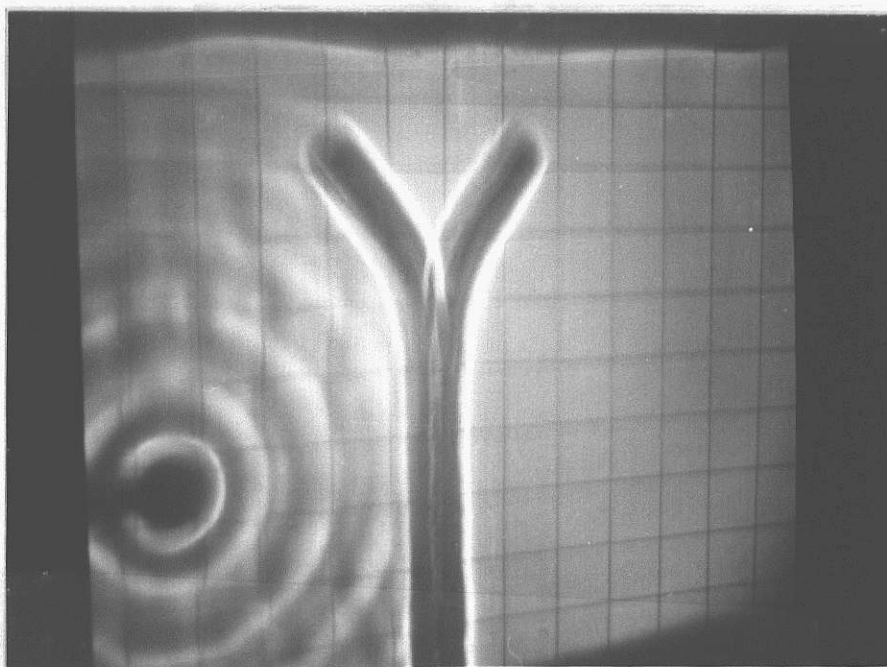
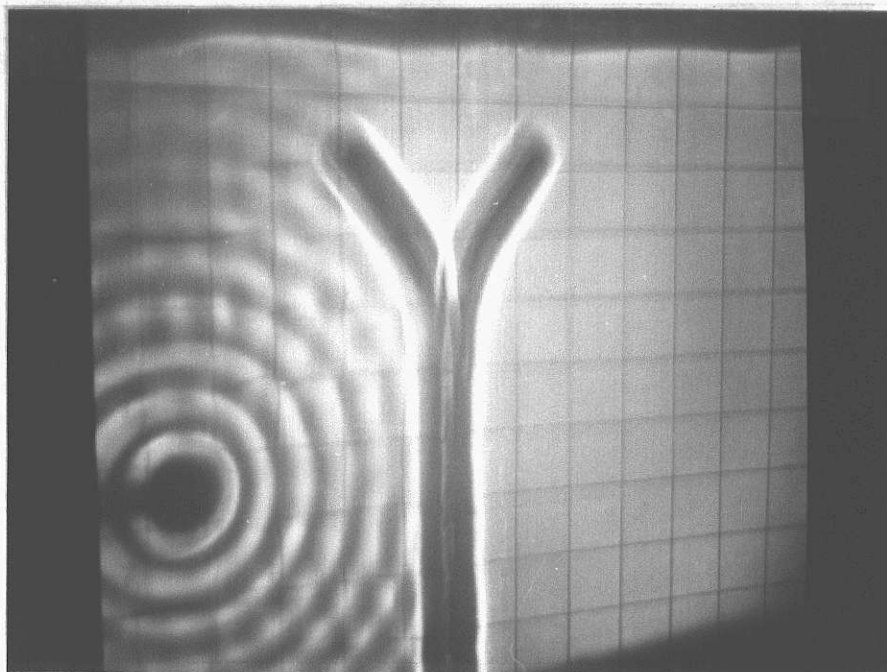
PHOTOGRAPHS OF RIPPLE TANK TESTS



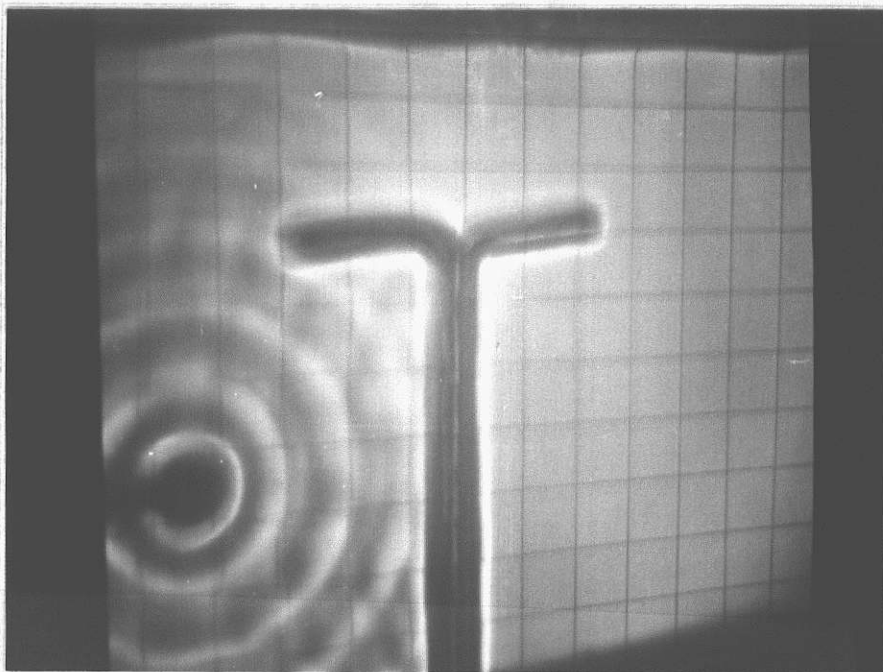
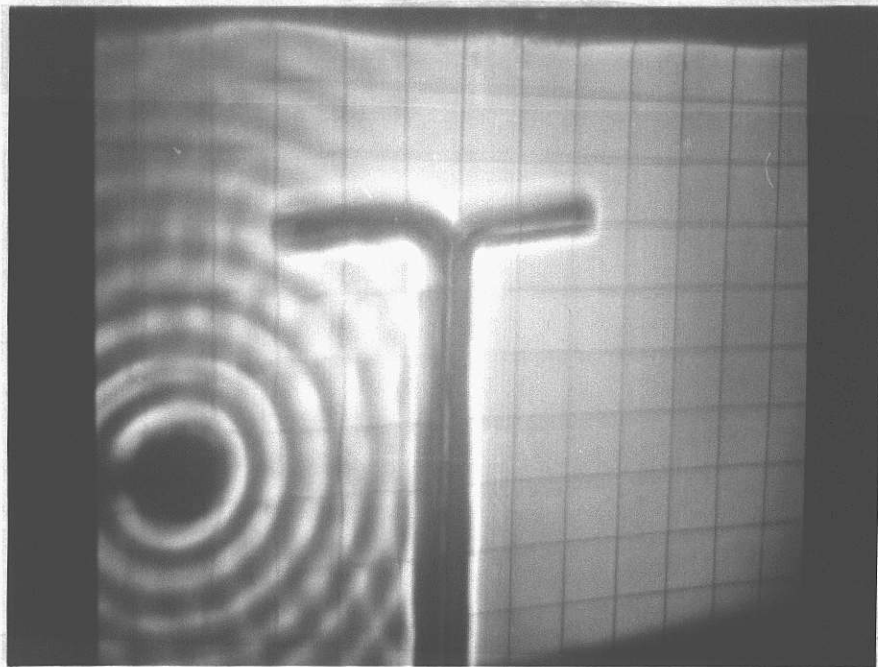
PHOTOGRAPHS OF RIPPLE TANK TESTS



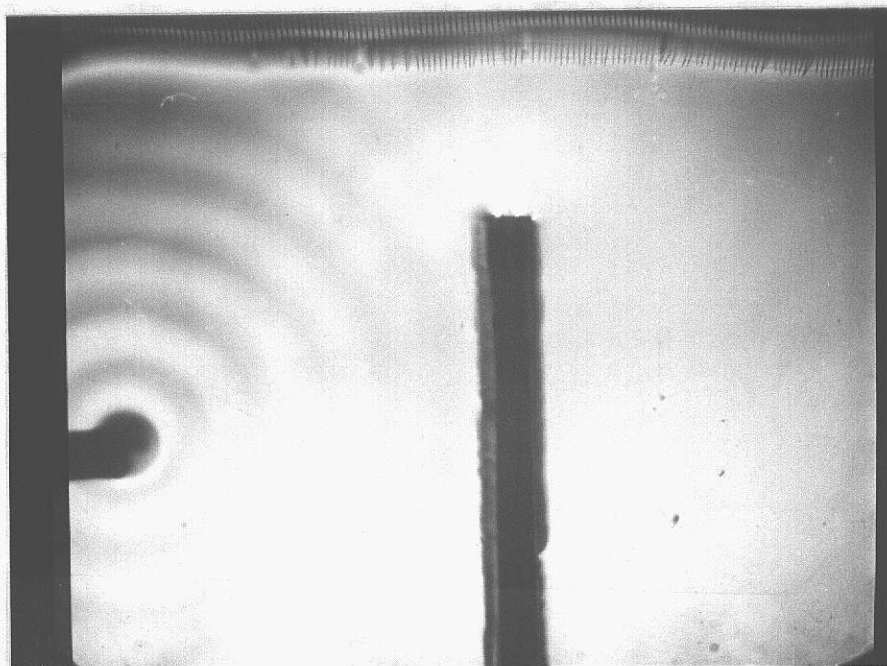
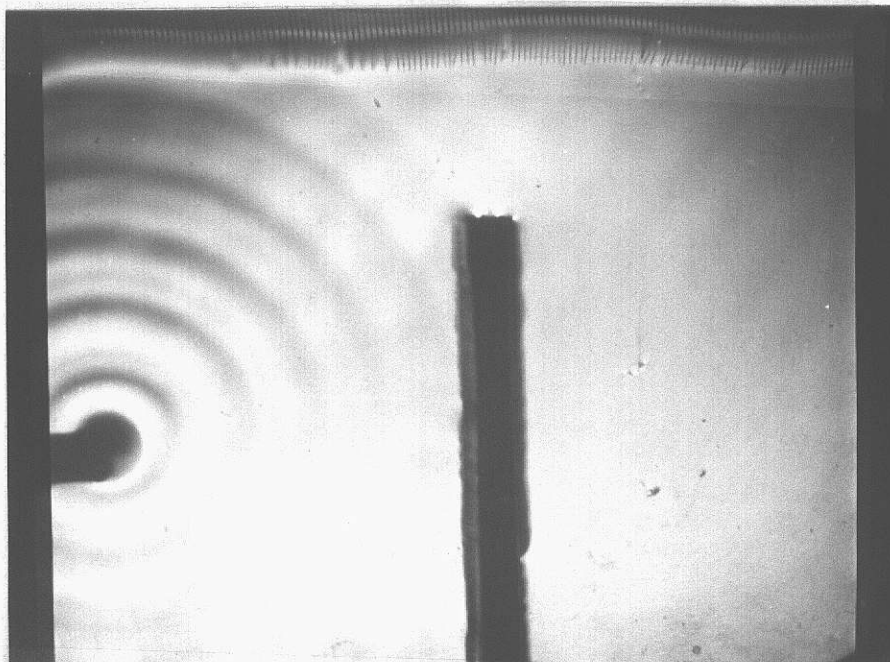
PHOTOGRAPHS OF RIPPLE TANK TESTS



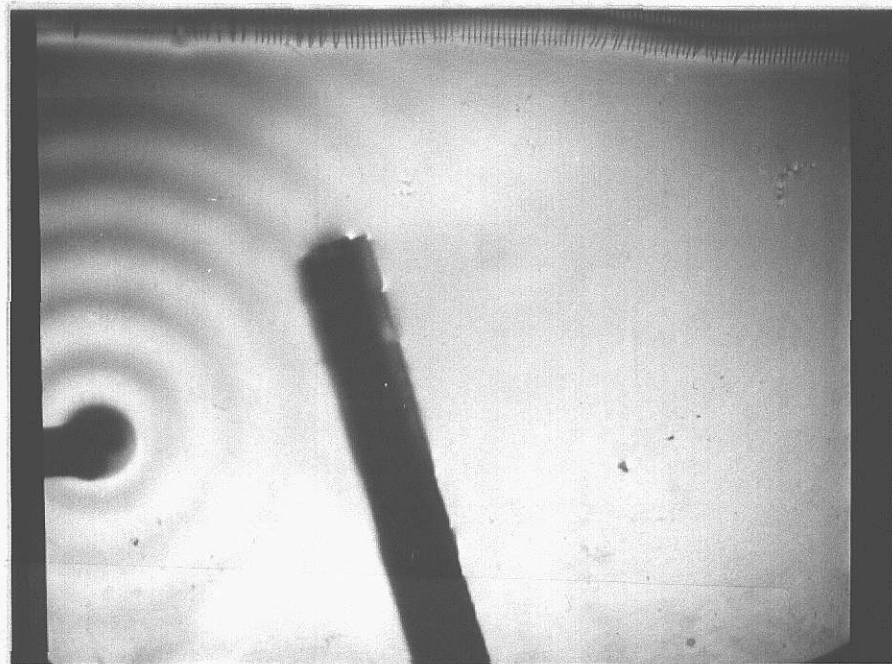
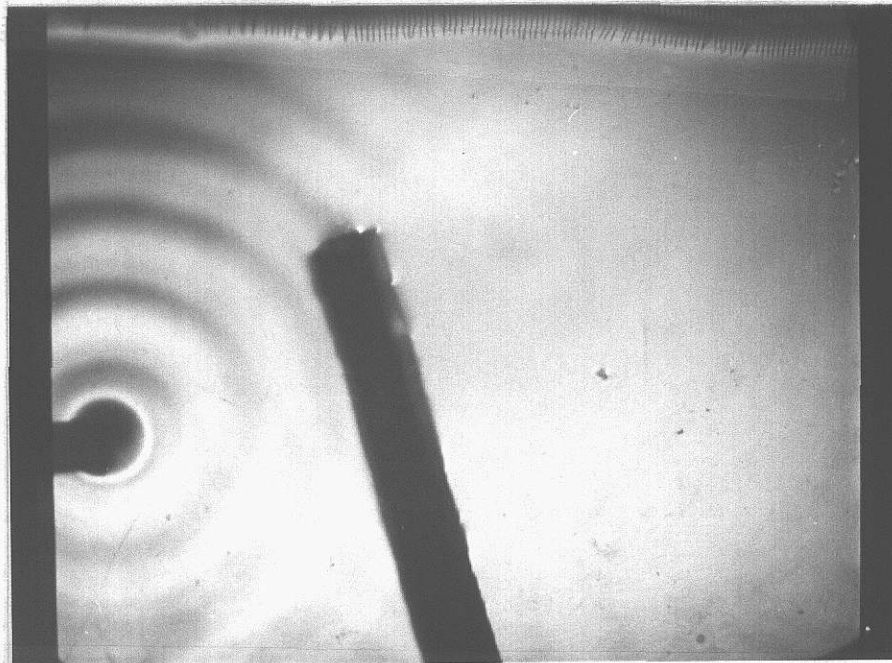
PHOTOGRAPHS OF RIPPLE TANK TESTS



PHOTOGRAPHS OF RIPPLE TANK TESTS



PHOTOGRAPHS OF RIPPLE TANK TESTS



PHOTOGRAPHS OF RIPPLE TANK TESTS

DESIGN DEVELOPMENT OF OFFICE LANDSCAPE
PARTITIONS THROUGH ACOUSTICAL RESEARCH

by

DANIEL C. KREPINEVICH

Bach. Arch., Kansas State University, 1970

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF ARCHITECTURE

College of Architecture and Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1971

In the United States today, almost half the work force spends approximately one third of their lives working in an office. When one spends a substantial amount of the day in this type of environment, it may have a great psychological affect on him. To insure the proper environment for the specific work to be accomplished, the space should be carefully designed and these psychological factors evaluated.

Today little is known of how people function in an office or what effect the environment of the office has upon the quality of work being done, the efficiency achieved or the communication between workers.

Today a new concept is being applied to the design planning and operation of offices. This concept has been used in Europe and is just beginning to be used in this country. It is called office landscaping. Office landscaping, as an approach to designing the office environment, embodies systems analysis, consideration of human factors and an intimate understanding of environmental control. As it has been tested and put into use in Europe, it shows signs of becoming a significant development in the planning of more comfortable yet more efficient offices. There is good reason to believe this is so, for office landscaping considers the office as a totality.

Office landscaping involves planning the office to eliminate all unnecessary visual barriers, (walls) and through careful grouping and inter-relationship to allow a worker to feel himself part of the total office rather than isolated in a small, tight, confining room apart from the overall operation.

Although the primary objective is to enable the office to function as efficiently as possible, it is equally important to remember that the staff must be made to feel comfortable and at ease: if they do not, productivity will suffer.

One of the major discomfort factors and an ever present source of distraction in the landscaped office is unwanted sound or noise. Noise may obscure or reduce the clarity or quality of communication, reduce one's ability to concentrate or it may produce other undesirable psychological effects. It results from the elimination of walls which isolate noise in the traditional office design.

It is the intent of this thesis to consider the criteria for the design of partial partitions and other surfaces which might be used to achieve acoustical privacy while not limiting or defeating the overall intent of the concept of office landscaping when used in a synthetic free field indoors, and by determining how sound flows in such spaces and how sound moves around barriers as typically encountered in office spaces.