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II-A-932

GUIDE TO THE SOUNDPROOFING OF EXISTING HOMES AGAINST EXTERIOR NOISE

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DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
Office of Development

OCTOBER 1977

FOREWORD

This report has been approved for general availability. The contents of this report reflect the views of the contractor, who is responsible for the facts and accuracy of the data presented herein, and do not necessarily reflect the official views or policies of the Los Angeles Department of Airports. This report does not constitute a standard, specification or regulation.

NOTICE

Form FHWA 121 (Rev. 5-73)

UNITED STATES GOVERNMENT

Memorandum

DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

DATE: March 15, 1978

SUBJECT: Technology Transfer: "Guide to the Soundproofing of Existing Homes Against Exterior Noise"

In reply refer to: HDV-21

FROM: Chief, Implementation Division
Office of Development

TO: Regional Federal Highway Administrators 1 - 10
Regional Engineer, Region 15

Distributed with this memorandum is a manual titled "Guide to the Soundproofing of Existing Homes Against Exterior Noise." This manual was prepared for the city of Los Angeles Department of Airports and is reprinted and distributed with their permission.

This manual should be of help to the designer in selecting and conceptualizing various methods of soundproofing existing homes. The manual would be useful with the previously distributed TechShare Report No. TS-77-202, "Insulation of Buildings Against Highway Noise," and the current distribution of TechShare Report No. FHWA TS-77-220 titled "Background Report on Outdoor Indoor Noise Reduction Calculation Procedures Employing the Exterior Wall Noise Rating (EWNR) Method."

This guide presents the various successful methods used in a 1970 pilot project to increase the noise reduction capabilities of existing houses for the Los Angeles Department of Airports. Three categories of modification from minor to extensive are covered. The guide also provides a basic understanding of the elements of noise control and the systematic method of soundproofing houses. This guide expands the repertory of methods and techniques of reducing the impact of highway traffic noise on its neighbors.

Sufficient copies for distribution to each holder of the Highway Noise Notebook in the region, division and State are included along with the basic distribution for TechShare documents.

Additional copies are available from the Implementation Division, Office of Development, HDV-21.

for Milton P. Criswell

GUIDE TO THE SOUNDPROOFING OF EXISTING HOMES AGAINST EXTERIOR NOISE

Report Number WCR 70-2

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March 1970

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I. INTRODUCTION

A pilot project was recently completed for the Los Angeles Department of Airports concerning the feasibility of soundproofing existing houses against aircraft noise. The results were reported in "Final Report on the Home Soundproofing Pilot Project for the Los Angeles Department of Airports," by Wyle Laboratories Research Staff, March 1970. One important outcome of the project was the determination of the structural modifications necessary to produce given increases in the noise reduction (the difference between exterior and interior noise levels) which the house provides for its inhabitants. This guide presents the various methods of increasing the noise reduction that were used in the project and found to be successful. It is not intended that the modifications described in this guide are the only possible means of achieving the desired results, but merely those that were deemed necessary in the above mentioned project.

Before proceeding further, however, it is necessary to define the word "soundproofing," a term that can easily be misconstrued and yet is useful since it sums up in one word the objectives of the modifications. In this guide, soundproofing means the act of modifying the elements of a house in such a manner as to increase the total noise reduction between the exterior and the interior. It is important to realize that this does not imply the complete exclusion of exterior noise from the inside of the house, but rather that the interior noise levels are reduced.

In the pilot project conducted for the Department of Airports, the houses chosen were in the immediate vicinity of the airport, and they were divided into three categories (Stage 1, 2, and 3) according to the degree of soundproofing that was to be achieved. Those houses close to the airport were, in general, designed for a higher noise reduction than those further away.

Stage 1 homes were modified so as to allow the owners the possibility of living with all the doors and windows closed. This stage entailed the least amount of modification in the series and included the introduction of a forced air ventilation system together with minor modifications to the doors and windows. Thus, no structural changes were necessary and yet the interior of the homes could be kept considerably quieter than was previously possible, especially during the summer months when ventilation is an absolute necessity.

Stage 2 homes were provided with a larger increase in noise reduction than achieved in Stage 1, by introducing major modifications to the windows and exterior doors in an attempt to bring their sound attenuating performance up towards that provided by the walls. In addition, it was found necessary to modify beamed ceilings when they occurred in this stage.

Finally, homes in the Stage 3 category were provided with more extensive modifications, relative to Stage 2, including alterations to the roof-ceiling systems, walls and floors, in addition to the introduction of a forced air ventilation system and modification of windows and exterior doors.

It is also possible to define these stages quantitatively in terms of the values of the total noise reduction obtained. Since one of the most annoying aspects of intruding noise is its interfering effect on speech communication, it is natural to be interested in the values of noise reduction in the frequency region most related to speech communication. Accordingly, the noise reduction is expressed here in terms of the average noise reduction obtained in the frequency region encompassing the three octave bands centered on 500, 1000, and 2000 Hz. This is termed the Speech Interference Level (SIL) noise reduction and the unit is the decibel (dB). In terms of this quantity, the approximate noise reductions required of Stage 1, 2, and 3 are 25, 35, and 45 or more dB(SIL) respectively.

The acoustical modifications mentioned in this guide apply to typical houses which exist in the southwestern portion of the United States. In other areas of the nation where the climate is less mild and where the typical house structure is more oriented towards the retention or exclusion of heat, the methods and materials used in this project may not be suitable and in some cases, certain minor modifications may not even be necessary. However, the principles and basic approach to the problem of soundproofing would be the same in any area.

The following sections of this guide contain a brief description of the fundamentals of noise control including the transmission and absorption of sound, followed by some recommendations on a systematic approach to the soundproofing of homes. This then leads directly to a description of those soundproofing methods used in the pilot project which are felt to be best for future use.

This guide, and the recommendations herein set forth, are based on the specific results obtained in the pilot project for the Los Angeles Department of Airports, mentioned above. It is emphasized that this document is, in fact, a "guide" and is not to be relied upon solely in the conduct of individual soundproofing projects. It is contemplated that this guide will be used effectively in conjunction with other appropriate professional activity, in the performance of soundproofing projects. Wyle Laboratories accepts no responsibility for the results of soundproofing projects accomplished without specific professional consultation with Wyle acoustic specialists.

II. ELEMENTS OF NOISE CONTROL

Success in noise control basically depends on understanding the behavior of the interaction between sound waves and the materials with which they come into contact. Noise control is a subject that can be divided into two main categories; the transmission of sound energy through a material and the absorption of energy at or in the vicinity of the material surface. These two effects should be carefully distinguished since in general they are caused by different physical properties of the material. A material that allows only a very small transmission of sound energy is not usually efficient as an absorber of energy, and vice-versa. Understanding this basic difference would prevent many expensive errors by individuals who are unfamiliar with the basic principles of noise control. It is hoped that the following sections will clear up such misconceptions and provide an insight into the methods used in reducing the sound levels in buildings.

A. Sound Transmission Through Materials

When a sound wave reaches a panel of a given material, such as a wall or a window, some of the incident energy is reflected and the rest is transmitted through the panel to appear on the other side as a sound wave of reduced intensity. We thus say that the sound wave is attenuated by the panel. If the panel is very massive, the action of a sound wave will not produce a very high level of vibration in it, and hence the amount of energy transmitted through it will be small. Conversely, a thin, light panel will respond and vibrate readily when excited by the same sound wave, and the transmitted energy will be high. We can therefore see that the higher the mass of the panel, the greater will be the attenuation of the incident sound wave. Thus, more sound energy will be transmitted through a window than through a solid wall, or a door of equal area, a fact that is well known from everyday experience. In addition, the amount of attenuation provided by a panel increases, in general, as the frequency increases. Thus, the protection against high pitched sounds is much greater than against those of low pitch.

Of course, it is an oversimplification to say that the attenuation or transmission loss provided by a panel is dependent only on its mass. There are other physical properties such as stiffness, or, in the case of cavity walls, the effect of the entrapped air, that have to be taken into account and that complicate the problem. However, as a rule of thumb, it is satisfactory to consider the mass alone.

As we have just seen, the attenuation provided by a single window is less than that of a typical wall structure. Therefore, when a window is included in an exterior wall, the attenuation provided by the combined structure will be less than that of the wall alone, but will be greater than that of the window. Of importance here is the relative area of the window with respect to the wall; the greater the area of window present, the lower the resultant overall attenuation. In each room of a house, there exist a number of such elements including walls, floor, ceiling, windows, and doors which have to be taken together to determine the overall attenuation provided by that room against external noise. The importance of each element is determined by its individual attenuation together with the surface area which it occupies in the room. Therefore, the main concern in the majority of houses are the windows, not because they occupy a large surface area, but because they have a low attenuation by themselves. If the windows do take up a large wall area, as in the case of large sliding glass doors, the resultant attenuation is even less.

The relationship between the sound attenuation provided by a wall and the mass of the wall is realized only if there are no cracks or gaps present. This requirement usually is met by any particular element under discussion, but is not always achieved at the joints where different types of elements meet, such as at door and window frames. At these points there is often a visible gap in the construction through which sound waves may pass. These gaps at the edges of doors and windows transmit sound waves at high frequencies more readily than sound waves at low frequencies. Thus, at high frequencies in the speech range, sound waves can pass freely through the small gaps, reducing the overall attenuation of the combined structure. Therefore, the first step in increasing attenuation is the sealing of all cracks and gaps.

B. Sound Absorption

The second category which affects noise reduction is sound absorption. The absorption of an incident sound wave occurs at or near the surface of the panel. There are various mechanisms by which sound waves can be absorbed, but by far the most common in building acoustics is what is known as the porous absorber, such as acoustic tile. This type of absorber is usually placed in contact with the interior surface of a wall or ceiling and operates by providing a frictional resistance to the incident sound waves as they pass through the material. When the waves strike the main wall surface, they are then reflected or transmitted as described previously. The net result is that the total amount of incident sound energy reflected by the wall is reduced, thus reducing the amount of sound energy in the room and hence in turn lowering the sound level. It should be mentioned that since the majority of absorbent materials have a low mass, they provide virtually no attenuation whatsoever if used as a wall structure by themselves.

It is now possible to make a clear distinction between sound transmission and absorption. The former determines how much sound energy passes through the walls and enters the room. Once in the room, the energy is further reduced by the action of the absorbents which therefore determine the sound level in the room resulting from the entering sound energy. A term that describes the combined action of these two effects is "noise reduction," which is defined as the difference in sound level between the exterior and the interior of the house, regardless of the mechanism of the reduction.

C. Sound Shielding

An important aspect in the application of noise control techniques to houses is the fact that the sound levels at various points around a house will differ by virtue of the acoustic shielding from the noise source provided by the house structure itself. This is similar to the formation of a shadow in the case of light. Shielding is, of course, beneficial since in most cases the sound levels on the shielded sides of the house will be less than those on the side facing the source. The only instance where this may not be so is where another building or high wall backs closely onto a shielded side; then the so-called shielded sound level may be increased by reflections. The actual amount of shielding in any one case depends not only on the dimensions of the house and the frequency of the sound, but also on the position of the source and whether or not it is stationary. Since low frequency sound waves do not travel in straight lines when circumventing obstacles (as the simple theory predicts) whereas high frequency waves do, it is natural to expect a higher degree of shielding to be obtained at higher than at lower frequencies.

If the noise source is an aircraft in flight, such that the flight path lies to one side of the house and not directly overhead, the shielding effect becomes a rather complex function of the frequency of the sound waves. This complexity results from the directionality of the sound radiated from the aircraft, the high frequencies being beamed forwards, and the low frequencies directed towards the rear. As the aircraft approaches, it is the high frequency "whine" that is first heard, so that the wall of the house farthest from the aircraft is shielded from these frequencies, while the wall facing the aircraft will have very little shielding. As the aircraft passes the house, the reverse will be true for the low frequencies. Both walls will have approximately the same shielding from the noise in the mid-frequency range. The wall facing the flight path will have a negligible reduction in level due to the shielding effect, while the wall farthest from the flight path will have higher shielding values at all frequencies.

It is, of course, possible to make use of this effect in soundproofing houses since the shielding is equivalent to an increase in attenuation of the shielded wall or window. Thus, the shielded elements of a house are not required to provide the same degree of attenuation as are the front and side walls.

D. The Systematic Method of Soundproofing Houses

The preceding sections have provided a basic introduction to the transmission and absorption of sound waves. This introduction can now be used to determine the measures that should be taken to increase the noise reduction provided by a house for its owner and family. Here, the emphasis is noise from aircraft, but the modifications will also reduce the interior sound levels resulting from automobiles and other nearby noise sources, including sounds from neighboring houses and yards.

The first step in approaching a noise control problem in the case of one of the rooms in a house is to determine the principal path, or paths, by which the offending noise is entering. Naturally, these will be by the acoustically weakest parts of the structure. An open window or exterior door is the worst situation commonly encountered that gives a very low noise reduction. In such a case, the attenuation provided by the walls and roof are of very little consequence as nearly all the sound energy enters through the openings. The remedy to this situation is of course simple, requiring the closure of the windows or doors, the result being a noticeable decrease in the noise level.

Once the openings are closed, it is more difficult to detect the weak link but usually it will be found to lie in the door and window frames, more particularly where the openable portion comes into contact with the frame. This cause occurs most often in the older houses where the weatherstripping is in poor condition, and where cracks have appeared in the wall near to the window or a door frame. Other paths of entry in this class of acoustical weak links include chimneys without dampers and most types of vents to the exterior, including mail slots. The first step of soundproofing involves closing or sealing these leaks. However, for the house to be habitable, it is necessary under these conditions to install an air ventilation system of some kind, not necessarily air conditioning unless dictated by the climate. This first stage, or Stage 1 as defined in this report, involves little work and can be relatively inexpensive.

Further reduction in the interior noise level requires great care since the weak acoustical paths are now not so obvious and the effort may be wasted on unnecessary items. In most cases, the next step is to modify the windows and doors themselves which, after the above are eliminated, become the dominating paths in terms of noise entry. A double window system is required together with a solid core type door, both of which must include good quality edge seals. The exceptions to these requirements occur on the shielded sides of the house which often require no further treatment beyond that dictated under Stage 1 modifications. If the house has a beamed ceiling, then modification of the roof may be necessary, partly on account of the poor attenuation characteristics of beamed ceilings but mainly because of the large area involved. These modifications form the second stage of soundproofing. If one desires an even higher degree of soundproofing, Stage 3 is required, which also entails treatment of the walls, floor, and ceiling on all sides of the house.

It can be seen that the approach towards the soundproofing of a house is carried out in a very logical manner by always treating the weak acoustical links first. The guidelines given above will be found to apply in the majority of houses encountered and if followed will enable the required noise reduction to be obtained in the most efficient manner.

III. SOUNDPROOFING METHODS

The methods used to soundproof homes in the pilot project for the Los Angeles Department of Airports were based on the rationale described in the previous section. In other words, Stages 1, 2, and 3 represented homes with gradually increasing values of noise reduction obtained by means of a step-by-step modification plan. The difference between one stage and a higher one involves a discrete increase in both noise reduction and costs. The purpose of this section of the report is to present the details of the modifications that were applied for each stage of required noise reduction. In each case, the description of the modification is sufficiently detailed so that an architect or designer can incorporate the design directly into the house plans. For the sake of clarity, the different stages for a particular house element (e.g., wall, window, door, et cetera), will be discussed consecutively under the heading of the element. In addition, the elements are arranged in an order that in general corresponds to the order of treatment as discussed in the previous section.

A. Windows

Most local building codes require that every habitable room in a house must have a certain area of openable windows, this area usually being proportional to the floor area of the particular room. This requirement is stipulated so as to provide adequate ventilation to the room as well as providing a possible exit in times of emergency. Its effect on the soundproofing of a house lies in its prohibition against permanently sealing all windows even though an adequate air supply system may be installed. Consequently, in this section, it is assumed that the windows described, or at least a part of them, are openable unless otherwise specified.

Stage 1:

- Wood double hung windows require a form of operable seal at the periphery of the movable section(s). This can be provided as shown in Figure 1 by including a strip of foam tape in wood or metal channels. The top panel should be firmly fixed in place and sealed with a silicone rubber sealant.
- Aluminum slider windows require an operable edge seal for the movable section(s) similar to that described under Item 1 above, and shown in Figure 2. The adjacent panel should be sealed in place with a silicone rubber sealant.

- Casement windows require an operable seal. It is not advisable to attach foam tape in such a way that it is compressed upon closure of the window because of the difficulty in effecting the closure. A more practical method is shown in Figure 3, where the foam tape is placed so as to form a small lined duct.
- Jalousie windows should never be used in any stage of modification and, if encountered in the house to be modified, should be replaced by any one of the recommended openable or fixed types.
- Fixed glass windows, such as "picture" windows, are good noise-barrier windows since they have no air gaps at their edges, but care should be taken during installation. The best installation is one where the window is firmly fixed in its frame with a resilient mounting material, such as silicone rubber or vinyl glazing beads, at all four edges. There should be no "rattling" whatsoever if the work has been done properly.

  In some cases, it may be possible to seal an existing openable window completely if allowed by the building code. Such windows should be firmly fixed and sealed at the edges with a silicone rubber sealant.

Stage 2:

- Wood double hung windows are to be removed and replaced with one of the Stage 2 type windows mentioned below. The usually poor fit of these windows in the frame prohibits their use as part of a double construction.
- Aluminum slider windows are to be modified by the addition of a 1/4 inch aluminum slider window in the same framework and separated by an air gap of 3-1/2 to 4 inches. Both windows are to have the edge seals as in the Stage 1 type shown in Figure 2.
- Casement windows are to be modified by the addition of an aluminum slider window with 1/4 inch glass as described under Item 2 together with the edge seals. This modification is only feasible where the casement is on the exterior side of the building (Figure 4).

- Complete replacement. If the original window is in poor condition, or if it is mounted in the framework in a way that does not allow an extra window to be installed at a spacing of 3-1/2 to 4 inches, an alternative approach is to remove the window and replace it with two single sliding types (Figures 5, 6, and 7) or a combined double type, such that the construction has an STC rating of not less than 39 dB.

- Fixed glass windows such as "picture" windows must be constructed of two panes of glass, the outer being 1/4 inch and the inner 3/32 inch in thickness, separated by a least a 3 inch air gap. If the window is constructed on site, it is necessary to include a trough of silica gel desiccant in the air space in addition to a careful sealing at the peripheries. It is also an advantage if the panes of glass are both frosted, so that any fogging that may eventually occur will not be noticeable. A commercially available double window that is hermetically sealed (Figure 8) can be installed directly. However, great care should be taken in the installation so that the sealing is not broken. If a commercial window is chosen, it should have an STC rating of not less than 39 dB.

  Where the building codes allow, it may be possible to completely seal one or more of the windows in a room. However, it is necessary also to provide a second glass pane, 1/4 inch in thickness, at a distance of not less than 3 inches. A trough of silica gel should be provided in the air space.

- Shielded windows of any type do not require a Stage 2 modification, but it should be ensured that they satisfy Stage 1 requirements.

Stage 3:

- All types of existing, single, openable windows should be removed and replaced with a commercially available double openable window (or two individual single windows) having an STC rating of not less than 49 dB. However, it is difficult to obtain a commercial product with such a rating. As an alternative, it is suggested that one be chosen with the same parameters as described under Stage 3, Fixed Glass Windows (see below). The operable version of this window will provide an STC rating of approximately 43 dB.

- Fixed glass windows such as "picture" windows must be constructed of two panes of glass, the outer being 1/4 inch and the inner 7/32 inch in thickness, separated by an air gap of at least 3 inches. If a commercial type double window is to be installed, it should have an STC rating of not less than 49 dB. The comments on installation and sealing are as described under fixed glass windows suitable for Stage 2 modification. An example of a commercially available window suitable for this category is shown in Figure 8.

  General Notes:

  (1) When installing any double window assembly, special attention must be given to the joint between the window frame, or casing, and the wall structure. In normal residential construction, a gap is sometimes found in this area that extends the full thickness of the wall. Ordinarily, this gap is merely covered by a piece of trim, but for noise control it should be filled to a depth of at least 1/2 inch with a permanently resilient caulking compound before the trim is applied.

  (2) In all cases where a double openable window is to be installed, it is necessary to arrange so that the openable portions of each are directly opposite one another to ensure ease of operation. To facilitate the cleaning of the stationary sections, a special type of window cleaning device should be provided.

  (3) All windows in a Stage 3 design are to be modified, including those on the shielded side of the house.

B. Doors

Stage 1:

- Hinged doors should be of a solid lumber construction, or solid core, and incorporate the following edge seals:

  a. Drop seals which are automatically actuated to seal the gap at the bottom of the door as it closes (Figure 9). The seal lifts up when the door is opened.

b. Edge seals at the top and sides of the door, which may be either metal strip weatherstripping (Figure 9), or consist of a continuous vinyl bulb inserted in an aluminum strip screwed to the frame (Figure 10). To avoid installation difficulties, the latter is preferred.

General Notes:

(1) Three hinges must be used to support the door, and the lock hardware should be of good quality since it will be subjected to unusual stress when holding continuous pressure against the stops.

(2) The threshold should be smooth hardwood and must be flat so that the drop seal on the door bottom can easily come in continuous, even contact. The reason for the smooth wood threshold is that during the last half or quarter inch of door swing, the drop seal is sliding horizontally on the threshold so that any grooves or bumps would cause the door to drag.

(3) Since these doors are heavy, the door frame construction must be substantial, although normal high quality residential construction is usually sufficient. Since the jamb on the hinged side carries the weight of the door, it must be firmly attached to the wall framing.

(4) All seals on doors must be very carefully adjusted so that firm contact with the door is obtained at all points. A simple method of checking is to close the door and view the seals from the interior of the building; there should be no light visible.

(5) Combination doors must be replaced with solid-core types.

(6) Doors on the side of the building shielded from the aircraft require no treatment.

- Sliding glass doors should incorporate acoustic seals at the three sides that come into contact with the main frame, together with the addition of absorption at the center joint, as shown in Figure 11.

Stage 2:

- Hinged doors are to be replaced with commercially available acoustic doors having an STC rating of not less than 36 dB. This type of door is usually supplied with gasketed stops (Figure 12) and an integral drop seal and is more effective than a simple, solid-core wood door.
- Sliding glass doors require the same treatment as described under Stage 1 modifications.

General Notes:

(1) Details relating to the suspension system and the seals are as described under Stage 1 modification.

(2) Doors on the shielded side of the building require a Stage 1 modification only.

(3) Mail slots should not be incorporated in the door assembly, but should be external assemblies mounted on a wall close to the main door.

(4) Peep holes which require a hole through the door of approximately 1/2 inch in diameter may be provided as long as the lens assembly is well sealed at the edges.

(5) A window may be inserted into the door if required, provided that the STC rating of the combination is 36 dB.

Stage 3:

- Hinged doors ideally should be utilized which have an STC rating of 46 dB. However, such a door is usually too massive to be adequately supported by a typical residential frame structure. It is therefore recommended that a commercially available door be installed as described in the Stage 2 modifications. In order to provide the additional noise reduction necessary, an acoustic shield (see below) should be installed. Great care is to be taken in the installation of the edge seals.
- Sliding glass doors are to be modified by the addition of an extra slider door assembly installed so as to provide a minimum air space of 3 inches between the glass surfaces (Figure 13).

The panels must be arranged as shown in Figure 14 so that the surfaces may be easily cleaned. The non-moving panel should be sealed with a silicone rubber sealant.

General Notes:

(1) All doors, whether they are shielded or unshielded, are to receive Stage 3 treatment.

(2) Details relating to the suspension system and the seals are as described under Stage 1 modification.

(3) In areas where a Stage 3 treatment is necessary and there is a direct line of sight from the flight path to an acoustical door installation, a shield wall should be constructed outside the building. The requirements of such a wallare that it should effectively shield an area that extends about three feet beyond the perimeter of the door. It should be constructed of wooden or fiberglass panels set into a framework that will withstand wind pressures.

C. Ceilings

Stage 1:

- No modifications are necessary to any type of ceiling.

Stage 2:

- Beamed ceilings are the only type that require modifications; however, there are two basic types of roof systems to be considered.
- The conventional beamed ceiling should be modified by removing any loose gravel or wood shingles (or any irregular roofing material) and installing a layer of 1-7/8 inch rigid fiberglass, on top of which is placed 1/2 inch plywood sheathing and a roofing material (Figure 15). It is important that the plywood not be nailed through the fiberglass into the bottom layer of wood.
- If the external side of the beamed ceiling is covered with Spanish tiles, the above method is extremely lengthy and costly; however,

it would be an approved method. An alternative is to modify the underside of the beamed ceiling in such a way as to retain the required aesthetic effect. The method is to install a separate ceiling in between the beams as shown in Figure 16, where the materials used are 1/2 inch sound deadening board and a new exposed ceiling of wooden tongue-in-groove planks.

Stage 3:

- Beamed ceilings in this stage require an additional roof system as shown in Figure 17. The new roof should consist of roofing on 1/2 inch plywood sheathing with an air space of not less than 4 inches, in which a layer of fiberglass insulation should be placed.
- Ordinary plaster ceilings may be modified by installing in the attic space a foamed-in-place urea formaldehyde chemical foam of a formulation that has been demonstrated not to cause any significant odor problem (Figure 18). Installation must be by a licensed franchised applicator, approved by the manufacturer of the product, using approved methods and equipment. Prior to installation, it is essential to determine that the chemical foam does not release any unpleasant odor. In any case, the contractor should be required to provide adequate ventilation and circulation in the attic space for a period of not less than 72 hours after the installation.
- If an alternative method is required, it is recommended that fiberglass batts be placed over the ceiling joists and covered with a single layer of 1/2 inch sound deadening board (Figure 19). There should be no gaps between the individual sheets of sound deadening board and the complete ceiling right down to the eaves should be covered.

D. Walls

Stage 1, 2:

- The experimental project in which the modifications described in this section were tested was conducted in the Los Angeles area. Consequently, the majority of the exterior walls were of the wood frame and stucco type, and it is this construction to which the modifications refer. It is not considered necessary to make any modifications to the more massive types of walls such as brick or concrete which occur in other regions of the nation.

- No modifications are required to any type of wall provided that it is of sound construction.

Stage 3:

- The walls on the unshielded sides of the building should be modified at the interior surface by the addition of 1/2 inch sound deadening board cemented to the existing wall to which a layer of 5/8 inch gypsum wallboard is cemented (Figure 20). Nails should not be used in this modification. Those walls on the shielded side of the building require no modifications.

General Notes:

(1) If the existing wall has an interior surface of wood panels, these should be removed and replaced on the new gypsum wallboard surface with a cement joint. Nails are not to be used.

E. Floors

Stages 1, 2:

- No modifications are required for any type of floor system provided that it is of sound construction.

Stage 3:

- Floors are to be treated by installing baffle boxes (with the inside surfaces covered with 1/2 inch rigid fiberglass) inside all of the foundation vent openings as shown in Figures 21, 22, or 23 depending on the floor configuration. These boxes act as sound "traps," allowing the passage of air to ventilate the underfloor space but absorbing much of the noise.

  It is important that the sound traps be of solid wood or plywood construction and that all of the gaps between the box and the foundation wall be solidly filled with caulking compound. Light that shows through anywhere but at the outlet end of the box also indicates a noise leak and must be filled.

General Notes:

(1) Local building codes may require that the space under wood floors be ventilated by means of a specific total amount of vent area, therefore the baffle boxes must be of the proper dimensions to satisfy this requirement.

F. Absorption

In some areas of a dwelling, notably the kitchen and bathroom, where there is an absence of sound absorbing materials, it may be possible to increase the noise reduction by 3 to 6 dB by the introduction of additional absorption. The simplest method is to lay a hard wearing carpet on the floor. It is, of course, essential that the carpet is capable of being easily cleaned.

G. Ventilation

In order to obtain the maximum benefit from the soundproofing methods described, it is necessary to effect temporary closure of all windows. Thus, some form of mechanical ventilation is required to make the interior of the house habitable in the summer months.

The types of air-handling systems that can be utilized are as follows:

- Forced air heating
- Forced air ventilation
- Forced air heating and ventilation
- Air conditioning

Any of these systems can in addition incorporate a combination of fresh and recirculated air using single or dual speed motors. Experience has shown that an adequate system is one incorporating forced air ventilation utilizing a two speed motor with a provision for adjusting the combination of fresh and recirculated air. In areas having a high summer temperature and humidity, however, an air conditioning system will be necessary.

General Notes:

(1) The fan for the ventilation system should not be placed in the roof space directly above a living room or bedroom. It is recommended that it should be placed above a hallway or bathroom. In addition, it should be either suspended from the roof or placed in high quality resilient mounts as an aid to preventing vibration being transferred to the ceiling and walls below.

(2) Air ducts, connectors, and elbows should contain an interior lining of at least 1/2 inch of fiberglass to provide absorption. The length of such a lined duct from the fan to the grille should not be less than 5 feet.

(3) For the ventilation cycle, a blower must be chosen that will change the air in each room at least eight times per hour.

(4) Only those manufacturers that supply sound power ratings for their products should be considered. The sound power produced by a blower depends, of course, on the amount of air it delivers. An example of an acceptable blower delivering 1400 cfm at a 0.5 inch static pressure in terms of sound power rating is:

Frequency (Hz)	125	250	500	1000	2000	4000	8000
Sound Power (dB)	71	64	63	62	60	56	52

where the sound power levels are expressed in dB referred to 10^{-12} watts, in the octave bands centered on the given frequencies.

(5) Ceiling mounted air supply grilles are the most efficient, and to provide an adequate air circulation, a complementary air exhaust/return grille should be provided in each room. It is recommended that the vanes in the grilles be non-adjustable.

(6) In some cases, an exhaust vent will penetrate a side wall or a roof where it is not practical to incorporate a lined sheet metal duct of sufficient length to provide the necessary noise attenuation. In this event, a plywood baffle box must be installed over the exterior end of the exhaust vent and lined with 1/2 inch rigid fiberglass absorbent as shown in Figure 24.

(7) Care should be taken to ensure that air is distributed evenly to all areas of the house.

H. Additional Vents

In addition to the ducts and vents associated directly with the air ventilation system, there are also some additional vents required for the normal functioning of the building.

- Underfloor access openings situated at the base of the building require some modification in a Stage 2 construction. The openings need to be covered with a baffle, as shown in Figure 25, which should be easily removable for access.
- Attic vent baffles should be provided in a Stage 3 modification whether the vent be shielded or not. If possible, the vent should be moved to the part of the roof that slopes away from the aircraft flight path and the baffle installed as shown in Figure 26.
- Kitchen vents that consist of a duct passing through the ceiling and roof should be modified in Stages 2 and 3 by introducing a bend in the duct (perhaps exiting the duct at a different part of the roof) and by providing a duct lining of absorbent material (Figure 27). It is necessary to cover the top of the duct with a rain cap.

  For kitchens which do not already have an exhaust fan, the closure of all windows will necessitate the introduction of a small fan in the kitchen vent in order to remove local fumes.
- Fireplace chimneys are a direct path for noise entry into a house. They can be treated by installing a steel damper, but it is sometimes difficult to ensure a tight fit between the damper and the frame. If the damper does not provide sufficient sound attenuation, an additional modification which may be made is shown in Figure 28. A one foot section of lined duct has been added to the chimney top. A simple method of determining whether this step is necessary or not is to listen at the hearth for any significant sound coming down the chimney during an aircraft flyby, with the damper closed.

I. Patio Walls

Exterior patios that are situated between two closely spaced houses, or between a house and a high wall may have high sound levels on account of multiple reflections occurring at the wall surfaces.

Some decrease in the levels can be obtained by placing absorption on the wall surfaces. The absorbent must be porous and be of a waterproof material that requires little maintenance. A suitable material is one consisting of chemically treated, mineralized wood fibers bonded together with cement and manufactured in panels 1 or 2 inches thick.

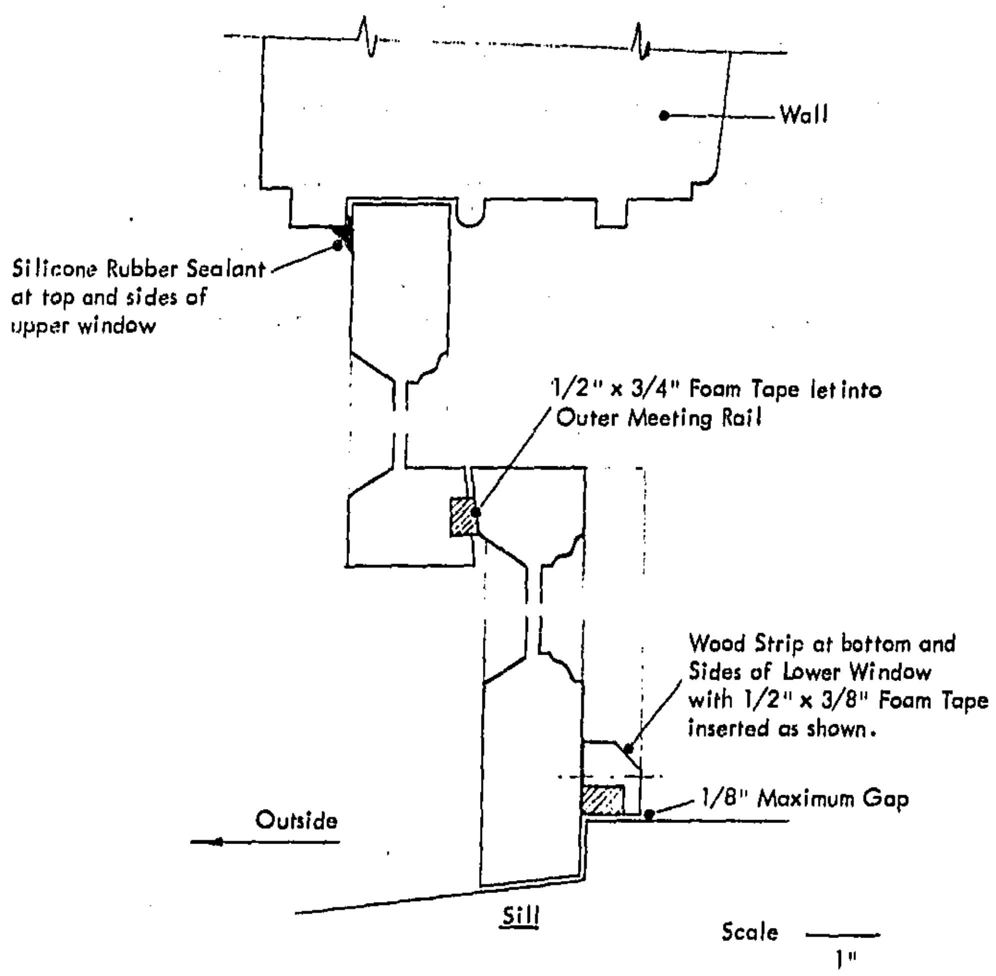


Figure 1: STAGE 1 DOUBLE HUNG WINDOW SEALS

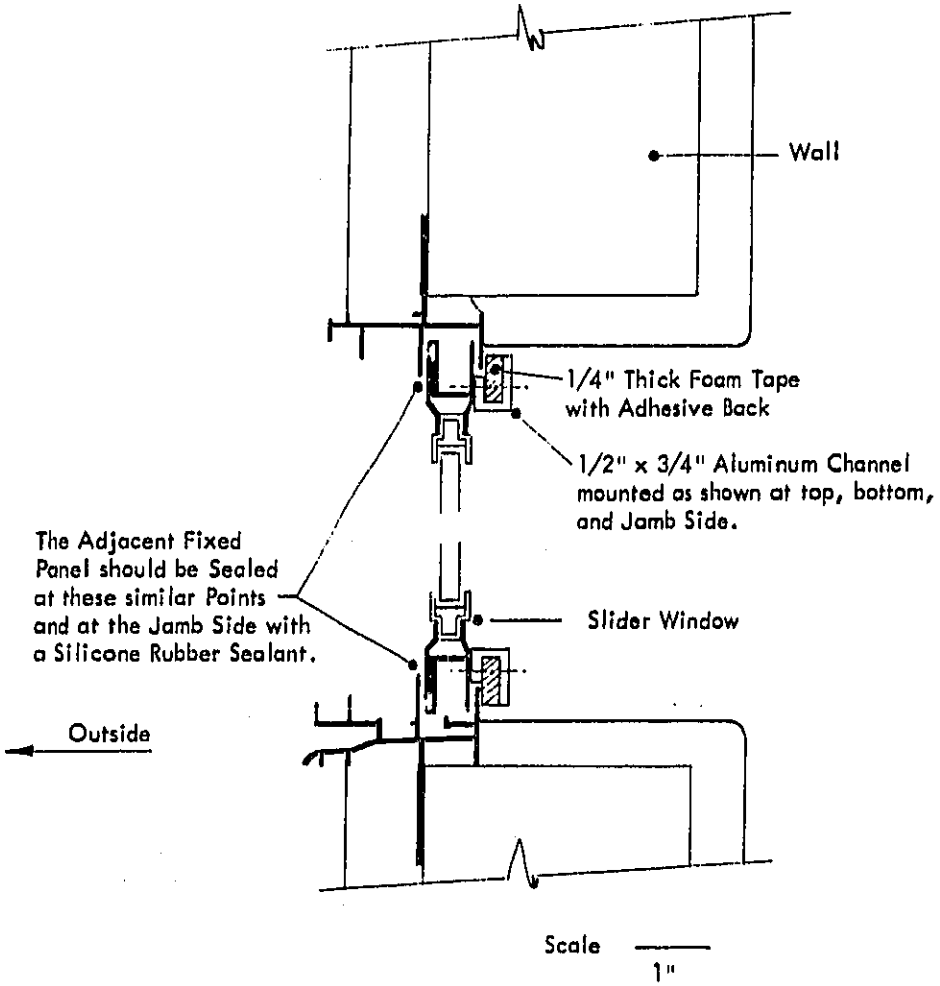
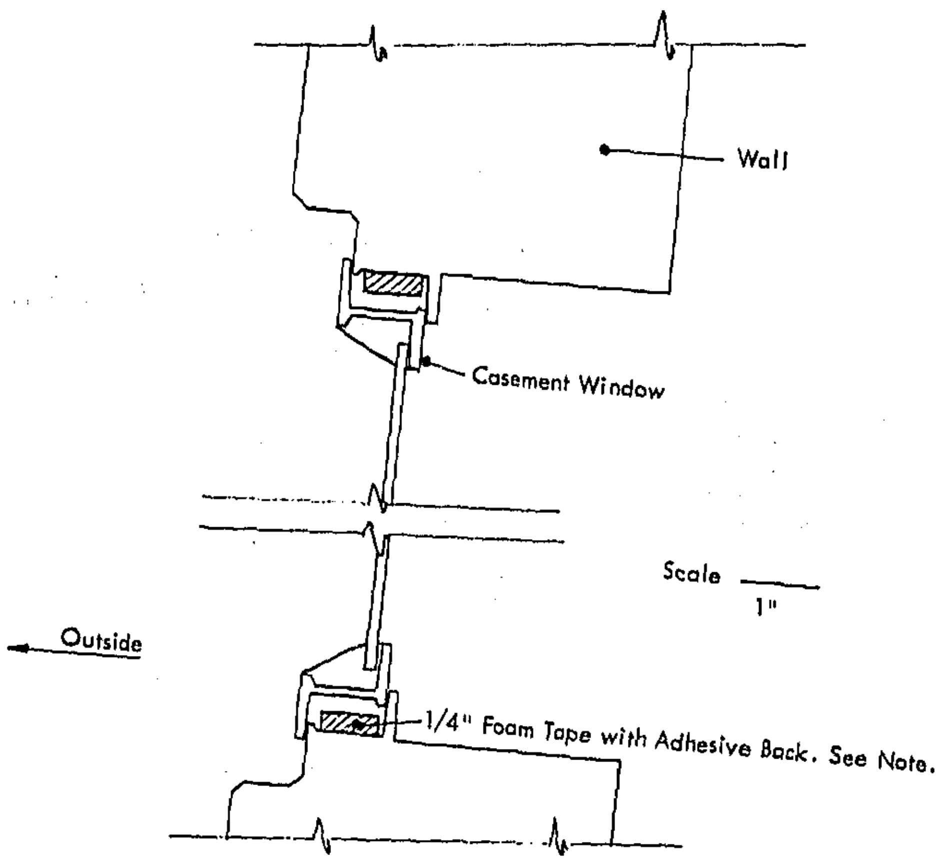


Figure 2: STAGE 1 SLIDER WINDOW SEALS



Note: On Existing Casement Windows the Paint must be removed to bare Metal in the Area where the Foam Tape will be installed and the Tape pressed onto a Bead of Fresh Silicone Rubber Sealant.

Figure 3: STAGE 1 CASEMENT WINDOW SEALS

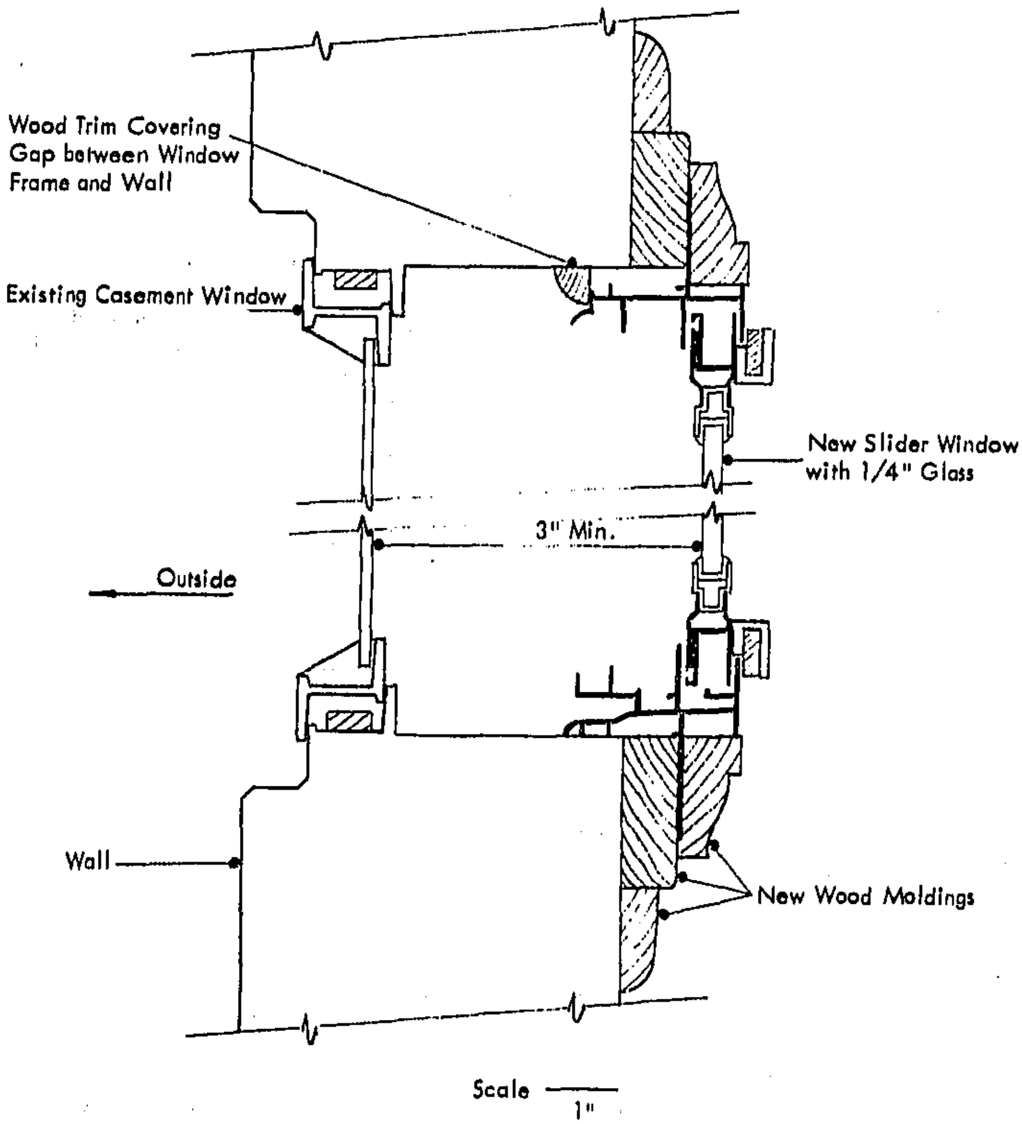


Figure 4: NEW SLIDER WINDOW INSIDE EXISTING CASEMENT WINDOW

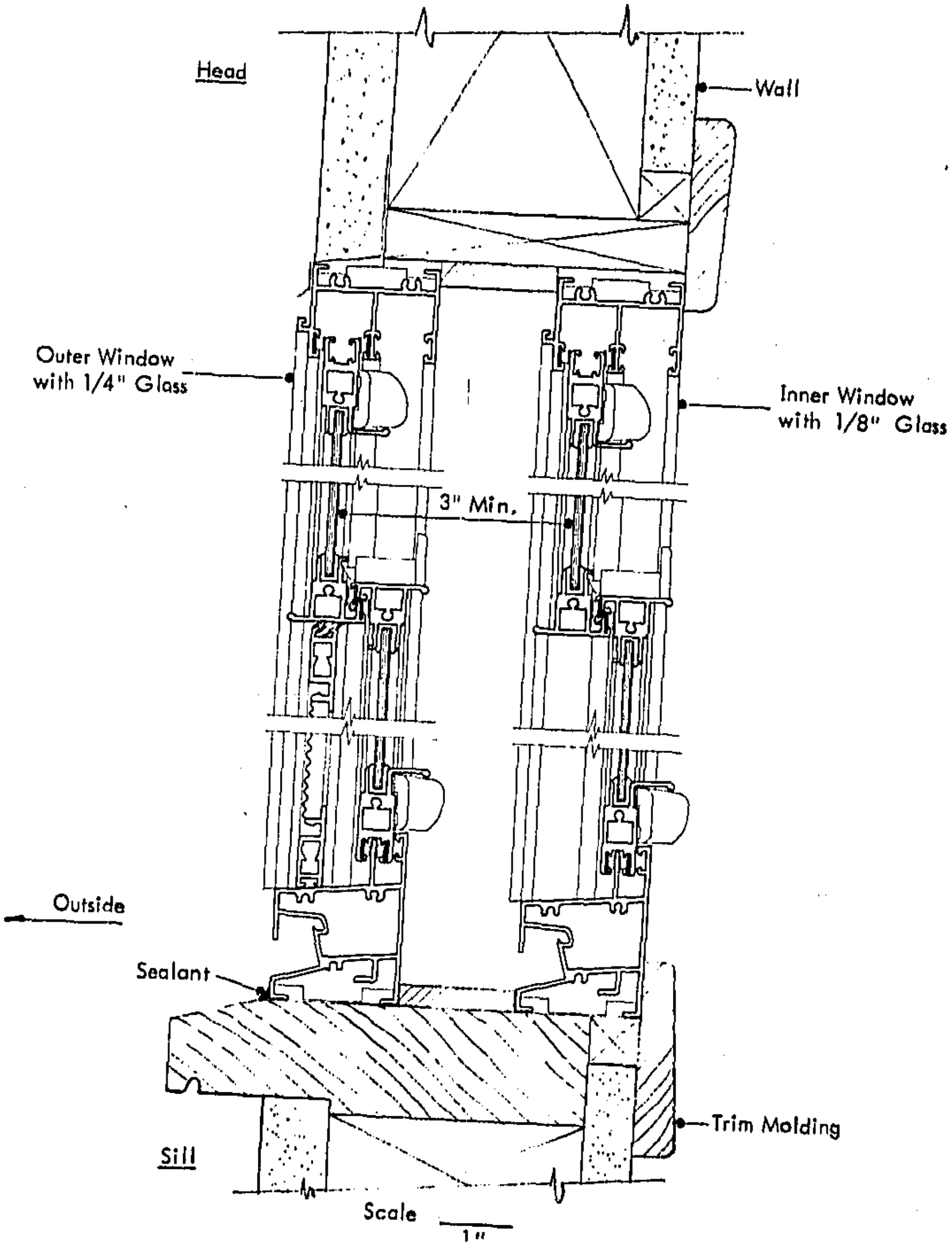


Figure 5: AN EXAMPLE OF A COMMERCIALLY AVAILABLE DOUBLE-GLAZED, DOUBLE-HUNG WINDOW

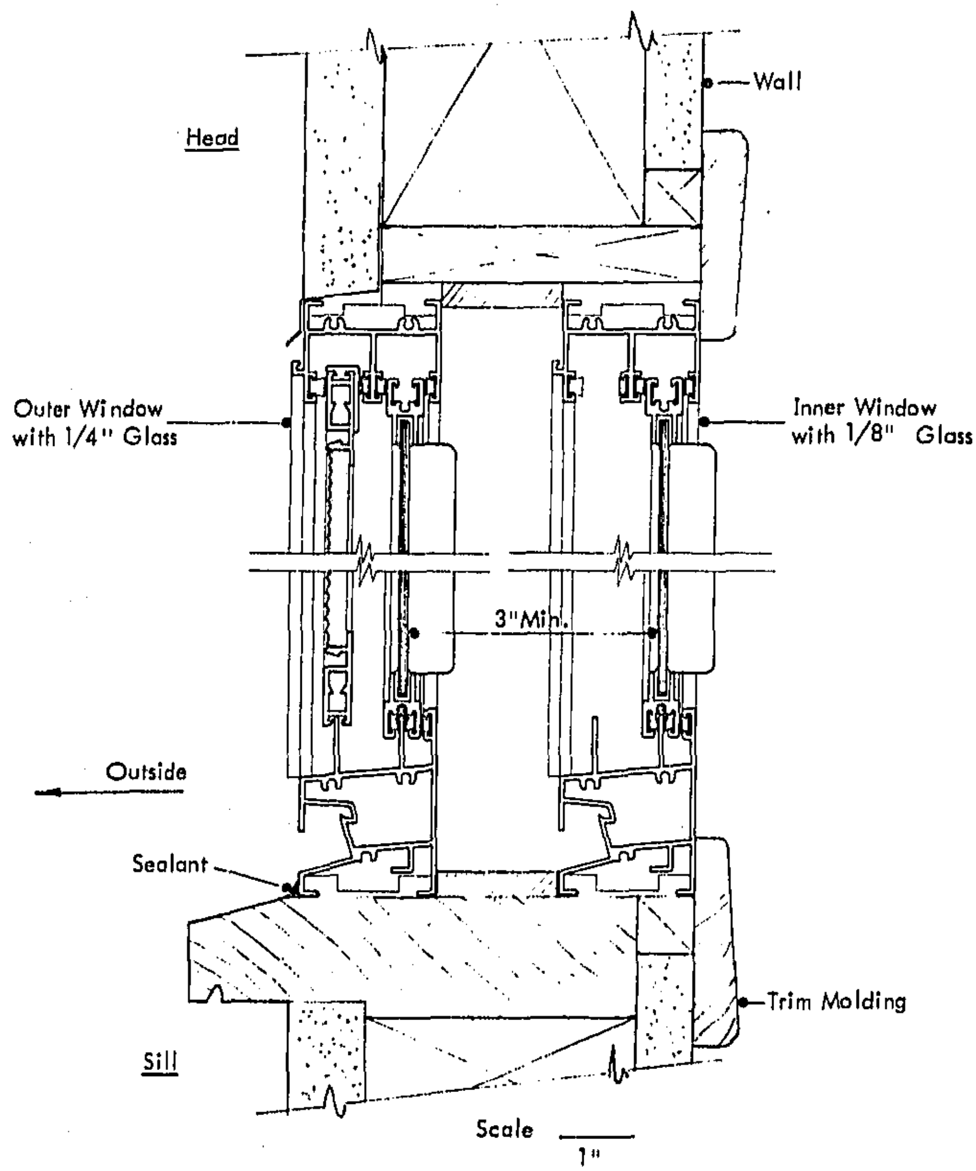


Figure 6: AN EXAMPLE OF A COMMERCIALLY AVAILABLE DOUBLE HORIZONTALLY SLIDING WINDOW

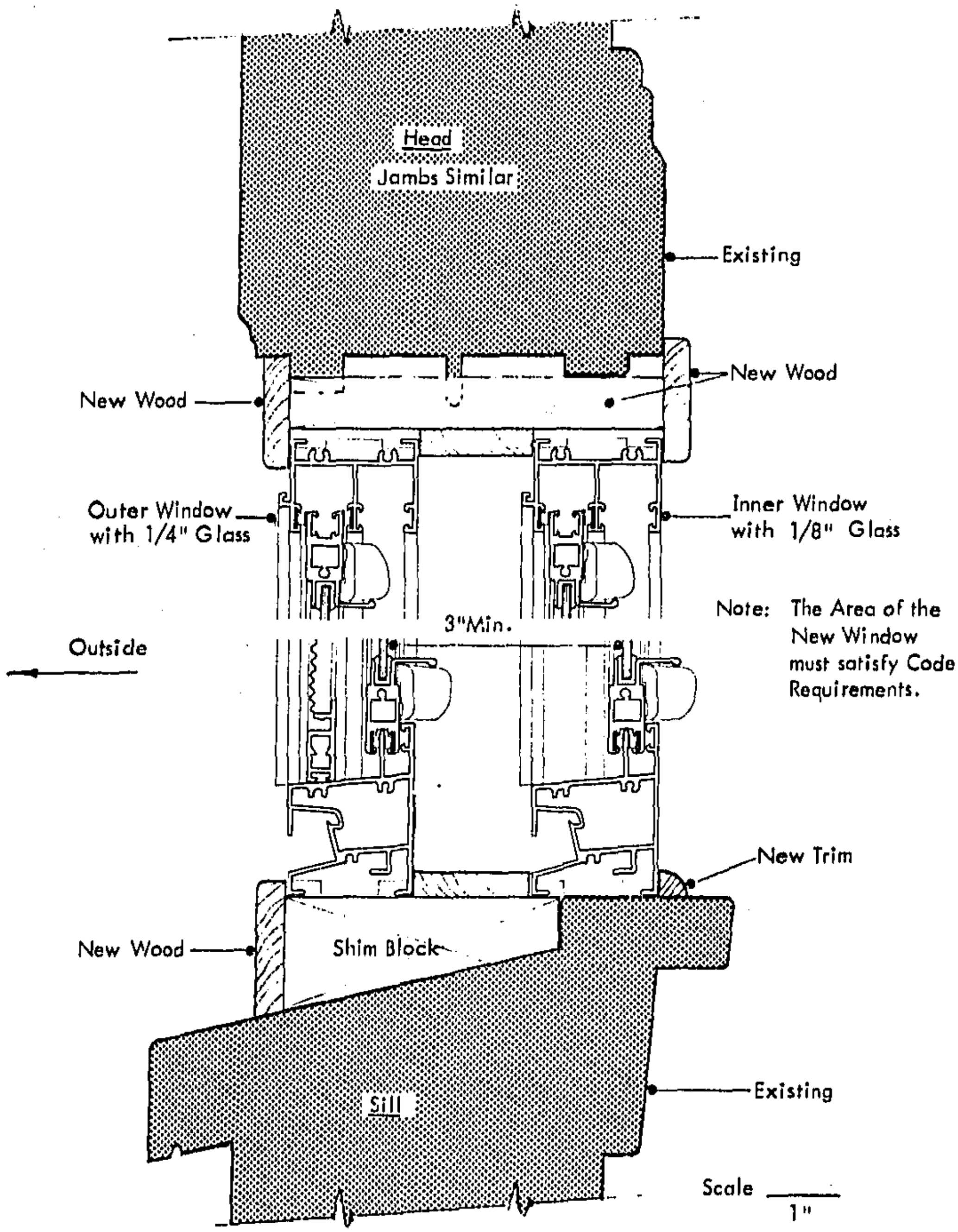


Figure 7: A METHOD OF INSTALLING DOUBLE WINDOWS WITHOUT REMOVING THE EXISTING WINDOW FRAME. (SEE THE NOTE.)

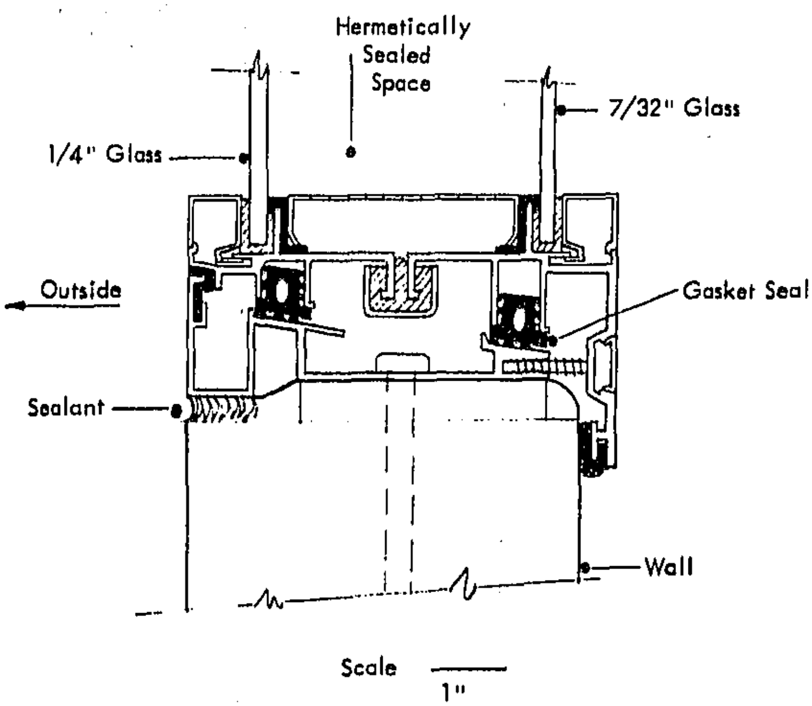


Figure 8: AN EXAMPLE OF A COMMERCIALLY AVAILABLE HERMETICALLY SEALED DOUBLE WINDOW

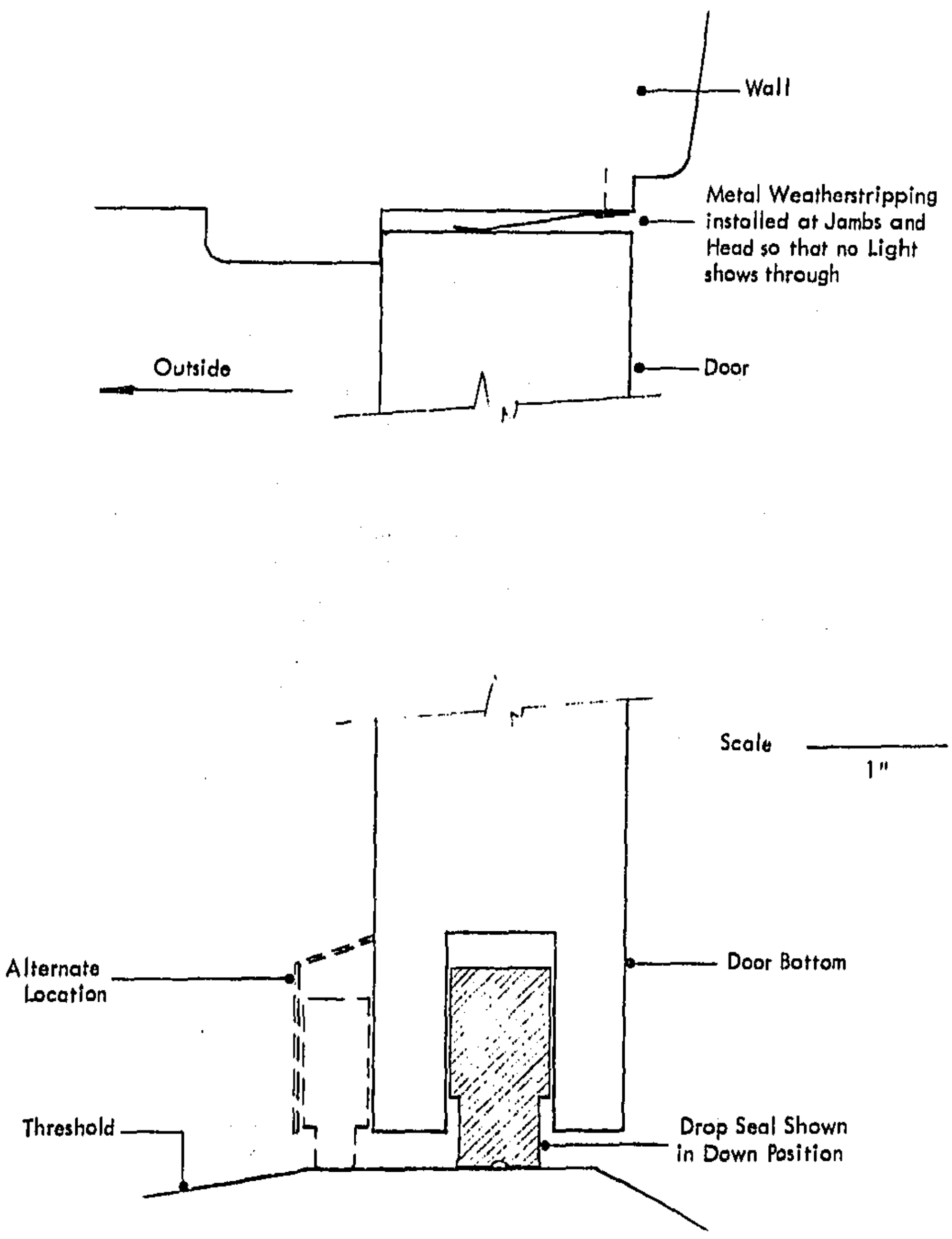


Figure 9: AUTOMATIC DROP SEAL AND STAGE 1 EDGE SEALS

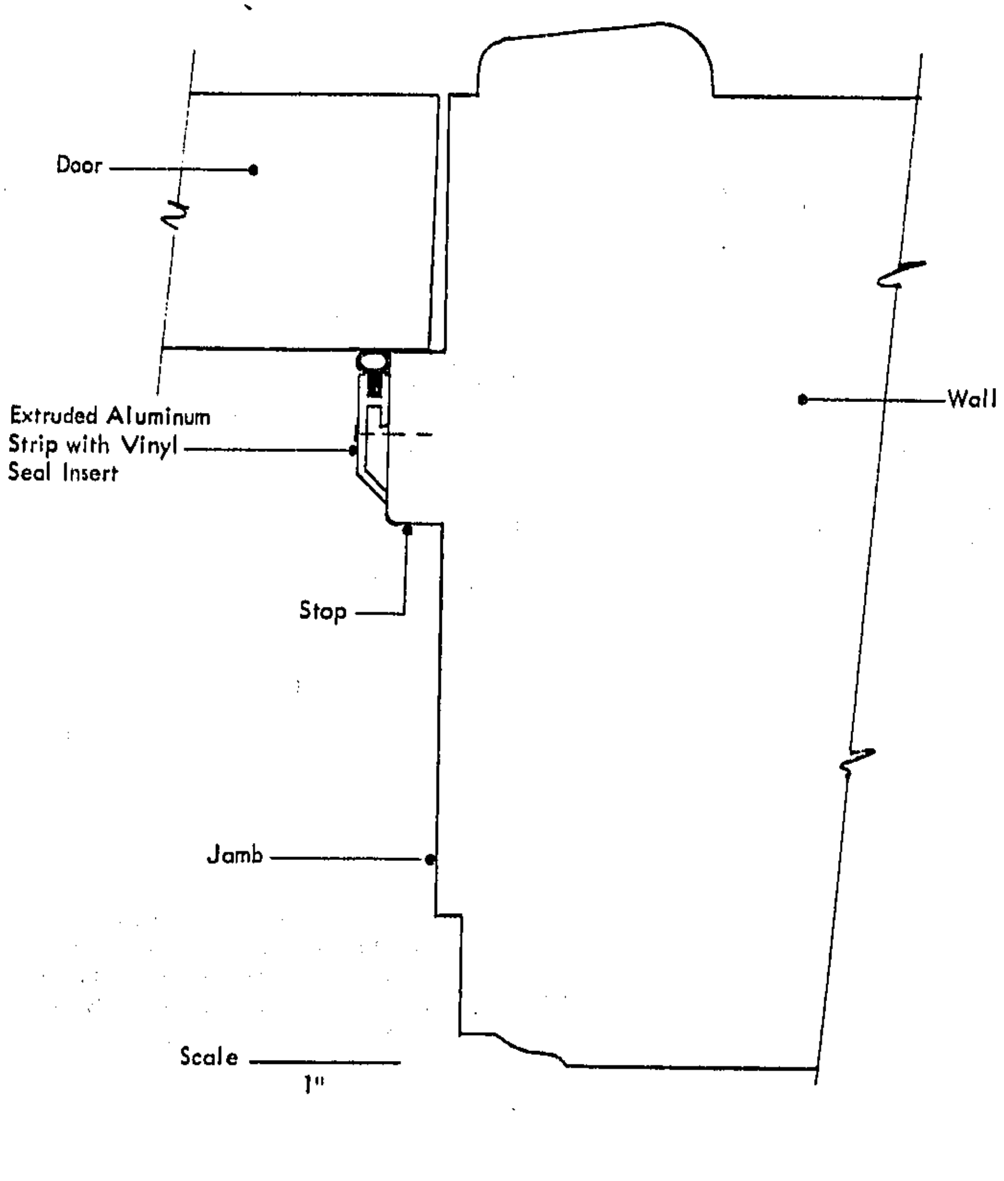


FIGURE 10: ALUMINUM-VINYL DOOR SEAL

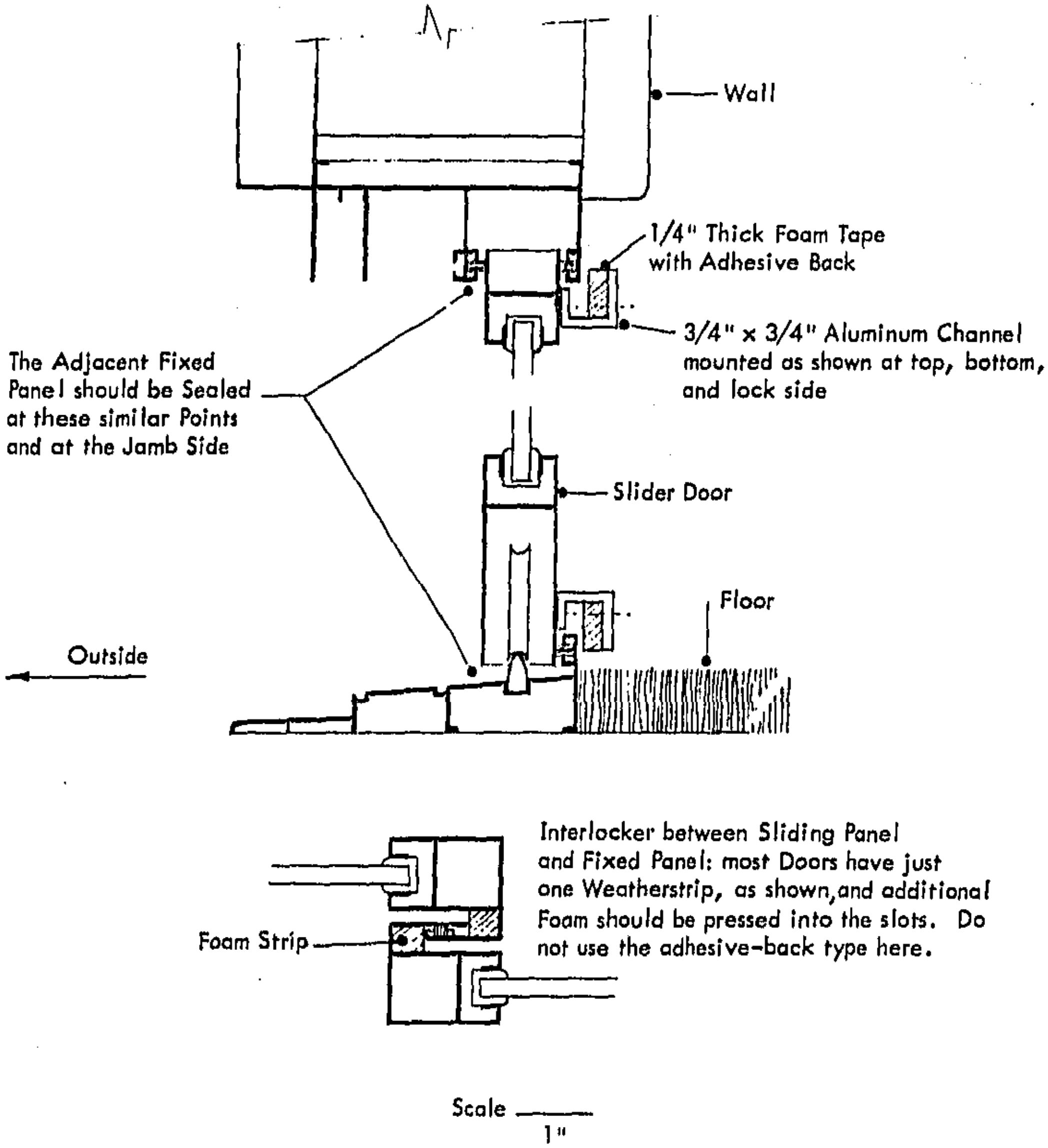


Figure 11: STAGE 1 SLIDER DOOR SEALS

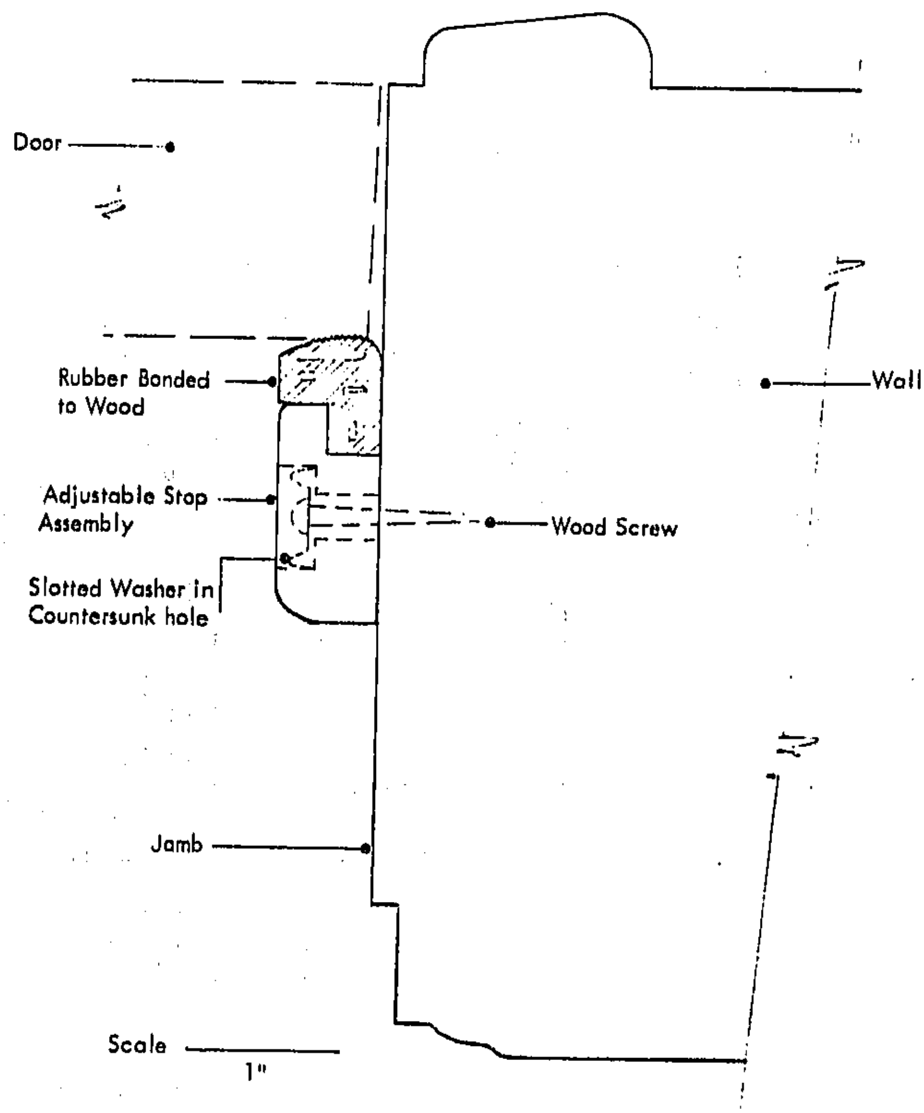


Figure 12: GASKETED DOOR STOP

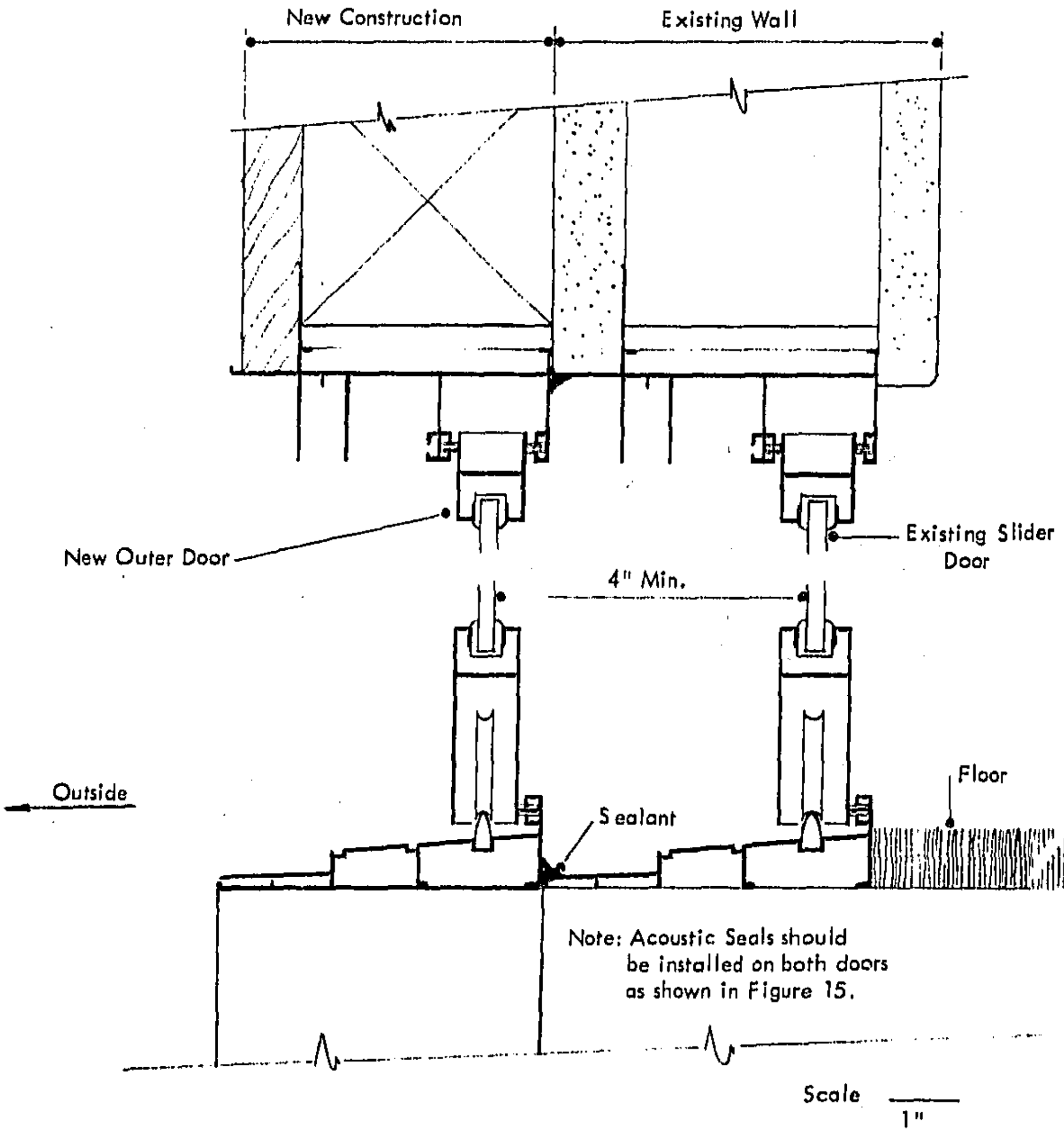
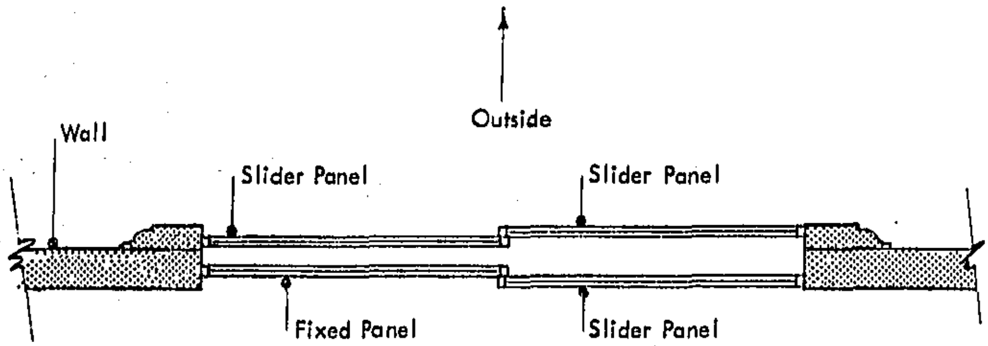


Figure 13: DOUBLE SLIDING GLASS DOOR



See Figure 13 for Details. The Slider and Fixed Panels must be arranged as shown to allow cleaning of all Glass Surfaces.

Scale ___ 12"

Figure 14: PLAN VIEW OF STAGE 3 SLIDER DOORS

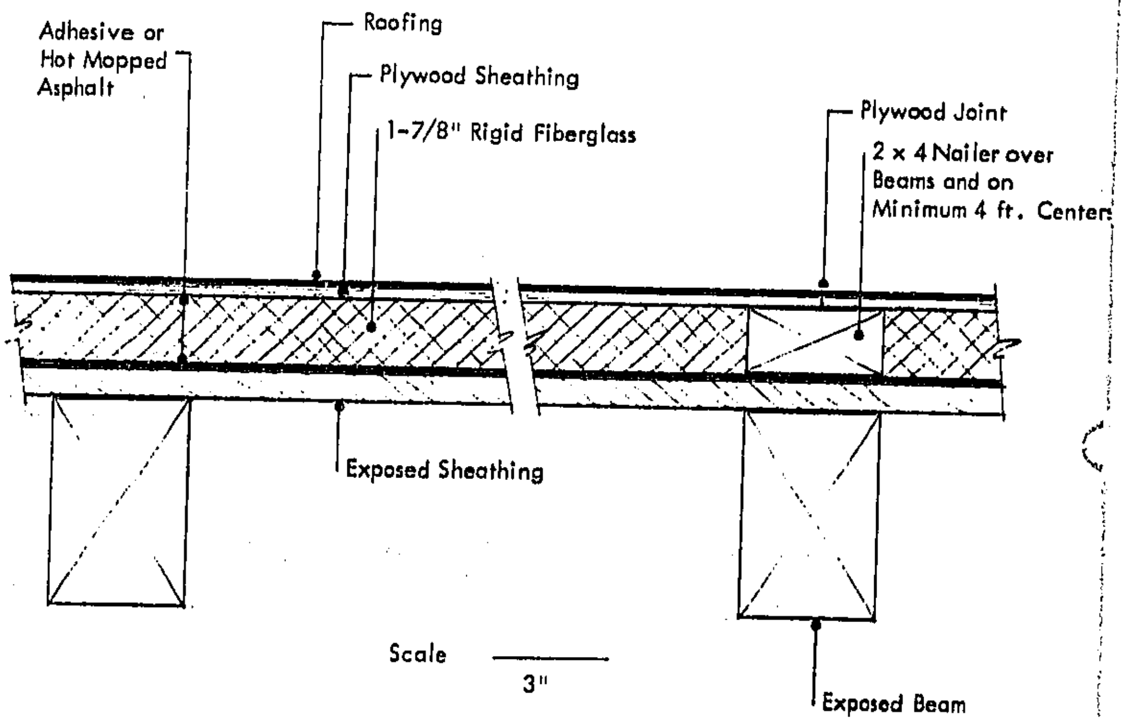


Figure 15: EXPOSED BEAM CEILING - STAGE 2, STANDARD ROOF

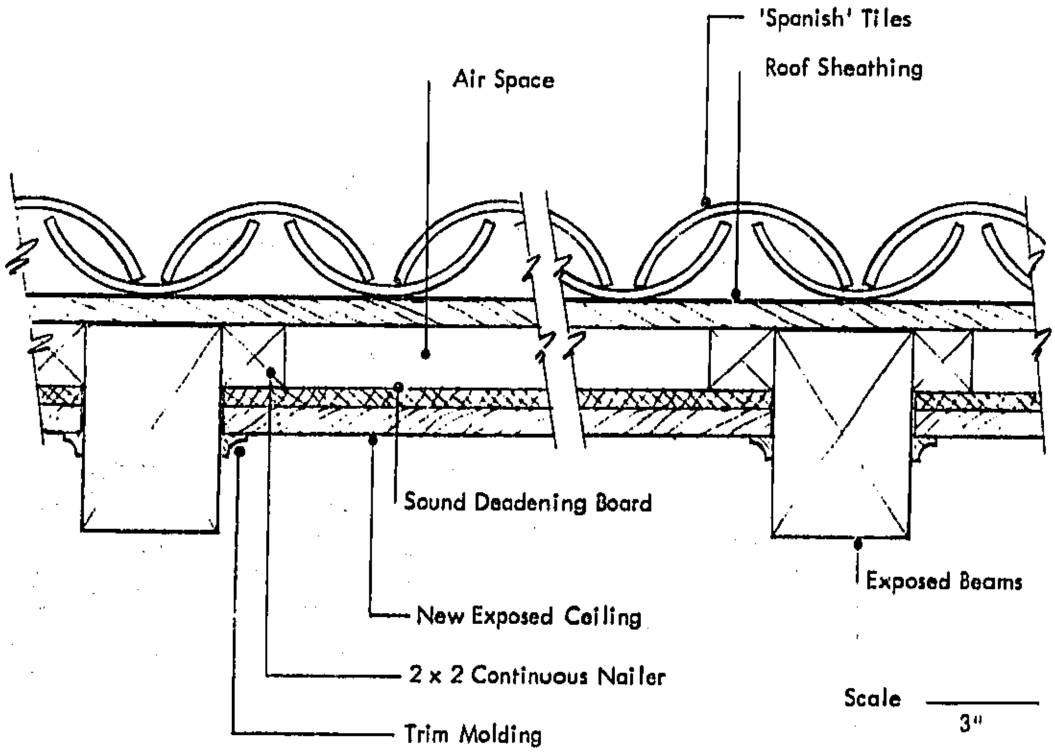


Figure 16: EXPOSED BEAM CEILING - STAGE 2, SPANISH TILE ROOF

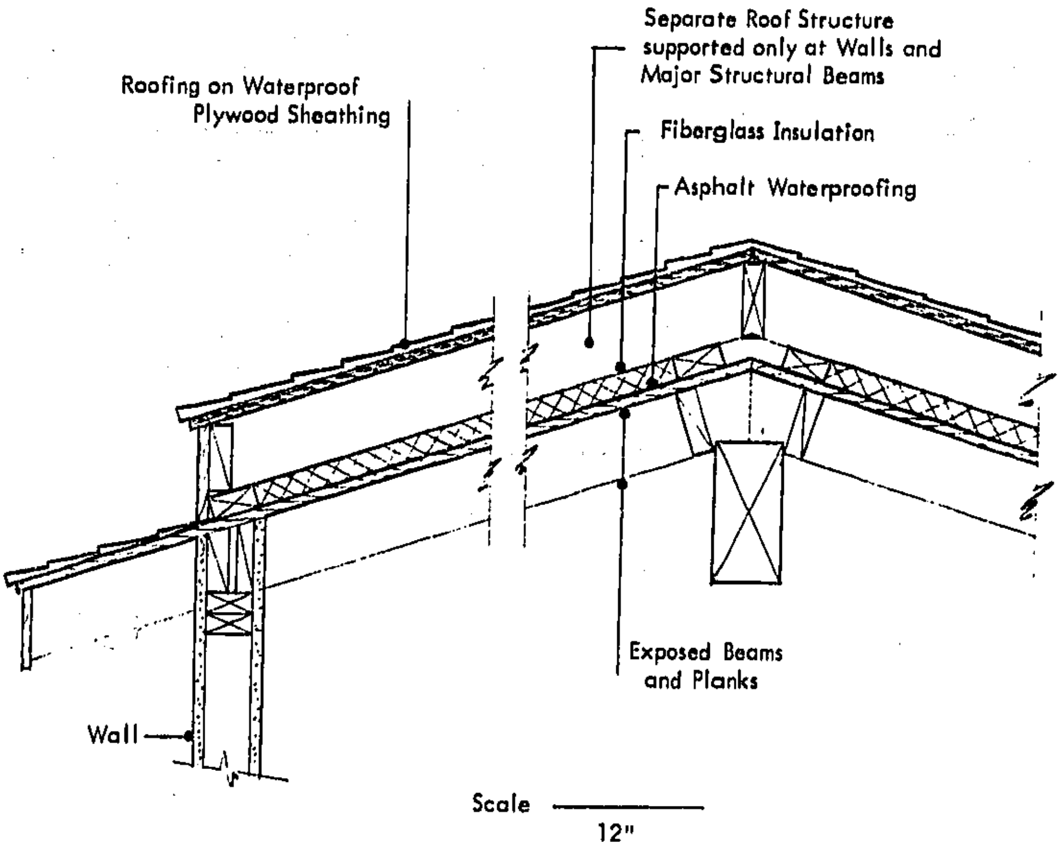


Figure 17: EXPOSED BEAM CEILING - STAGE 3

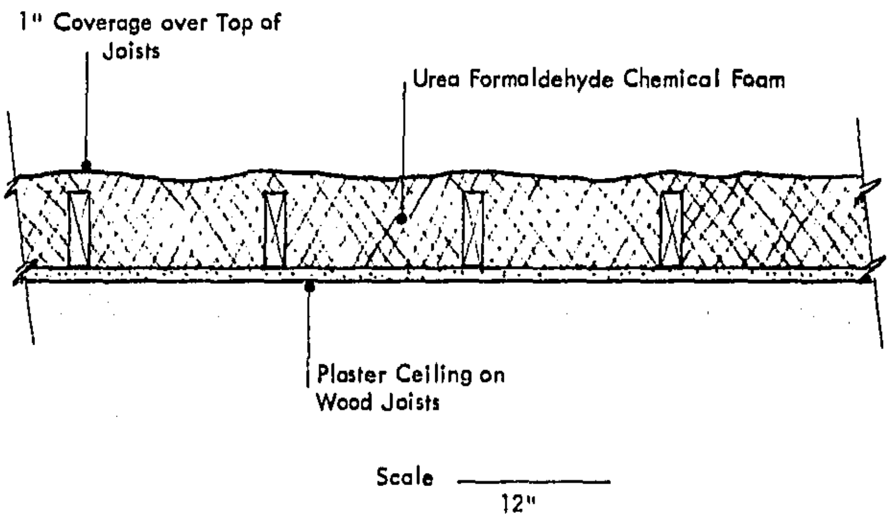


Figure 18: STAGE 3 CEILING TREATMENT

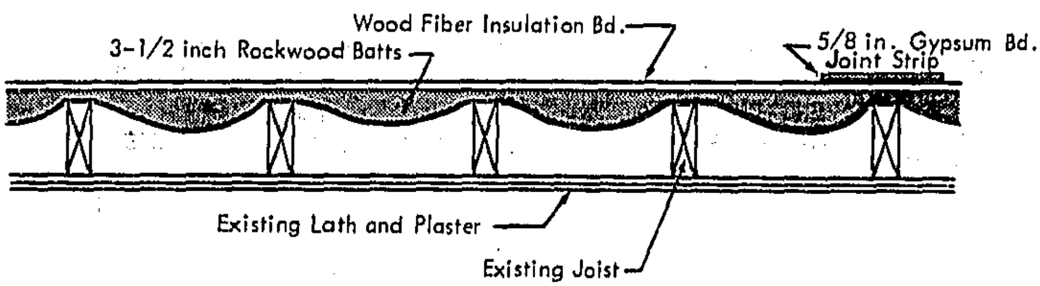


Figure 19: ALTERNATIVE STAGE 3 CEILING TREATMENT

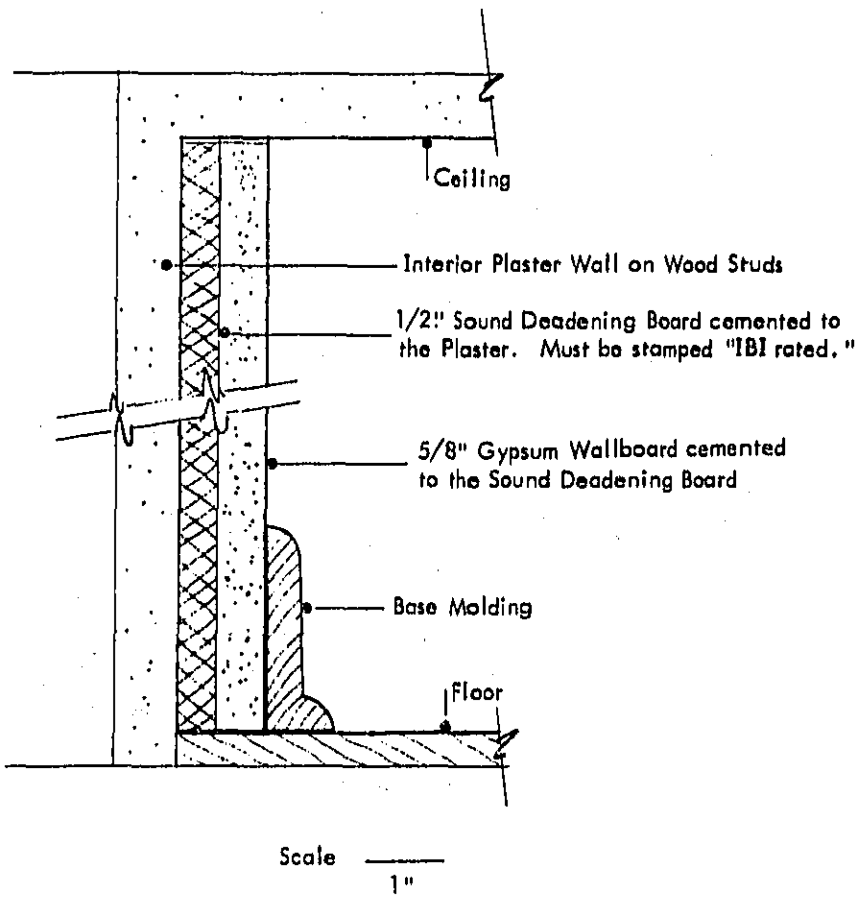


Figure 20: STAGE 3 WALL TREATMENT

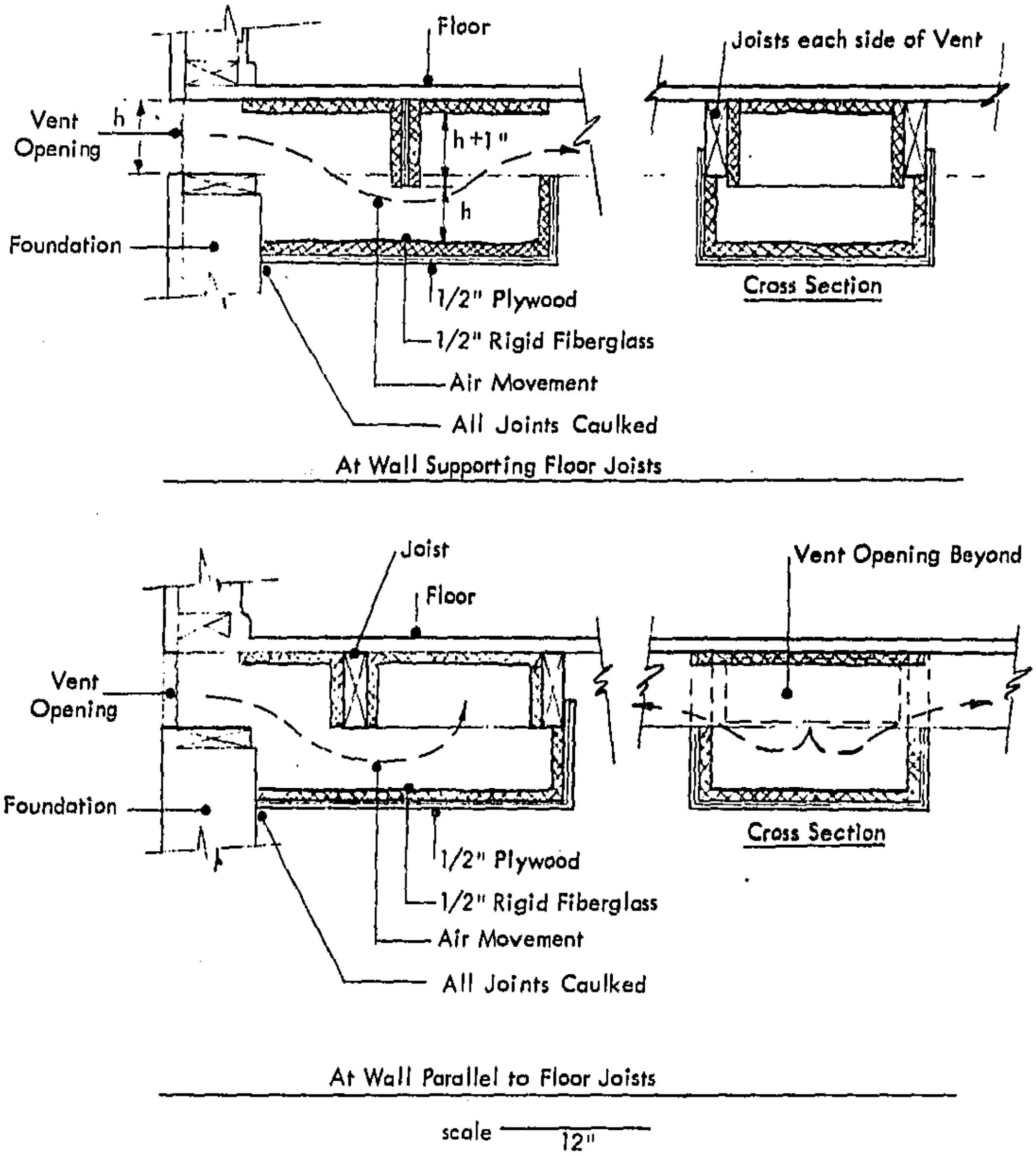


Figure 21: FOUNDATION VENT BAFFLE "A"

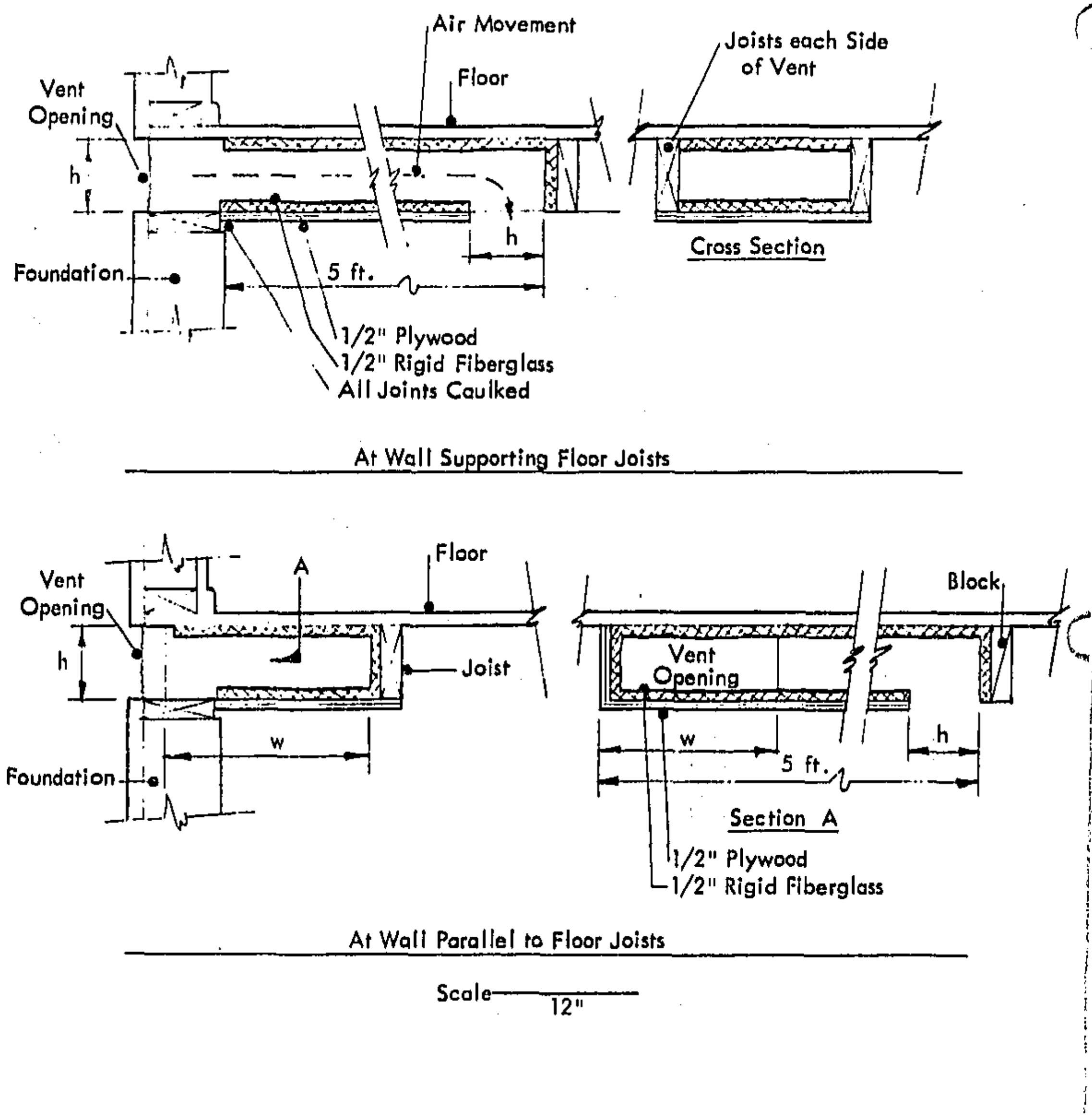


Figure 23: FOUNDATION VENT BAFFLE "C"

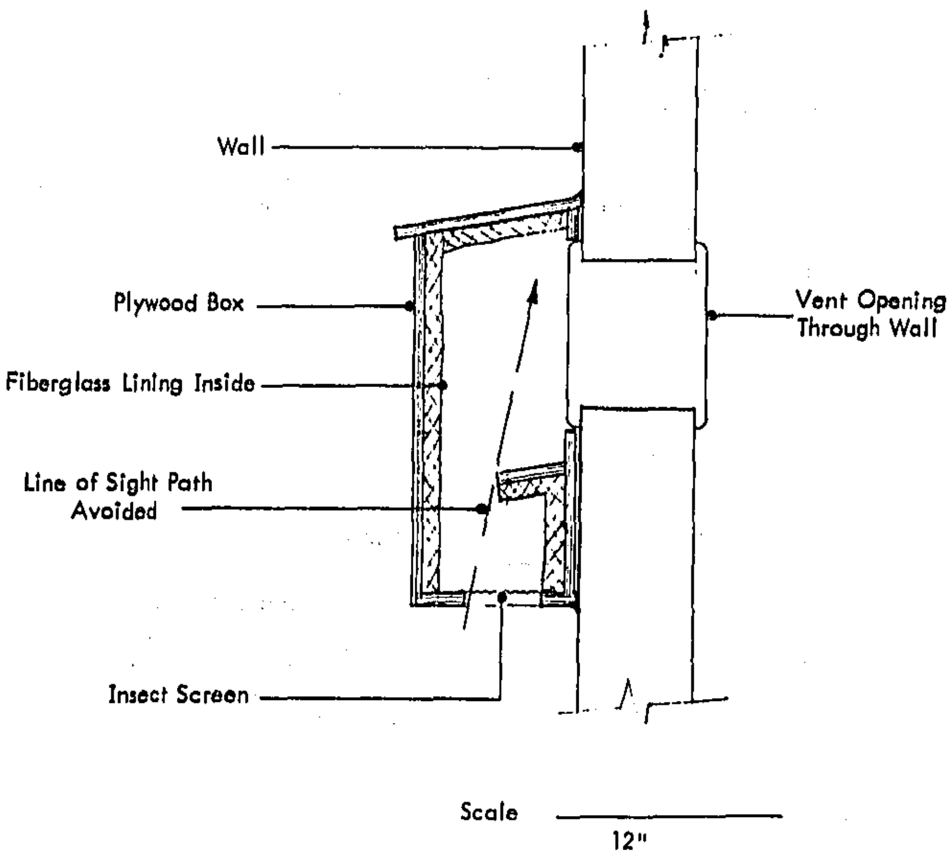
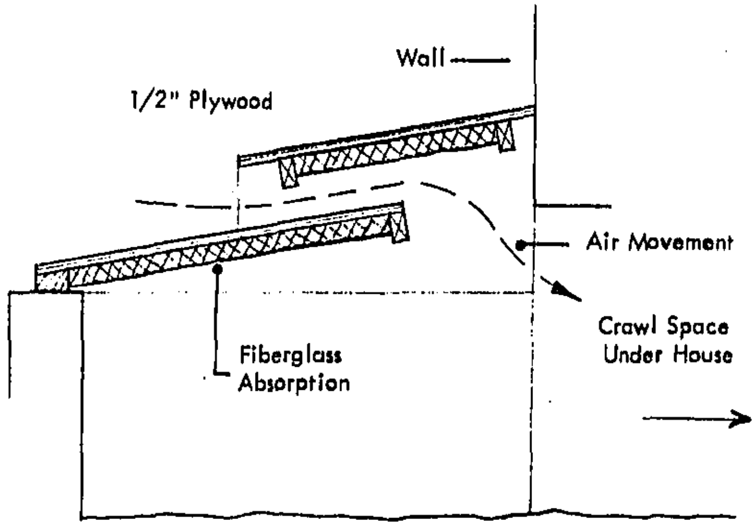


Figure 24: BAFFLE BOX FOR SIDEWALL VENT



Note: This baffle should lift off easily for access to the crawl space

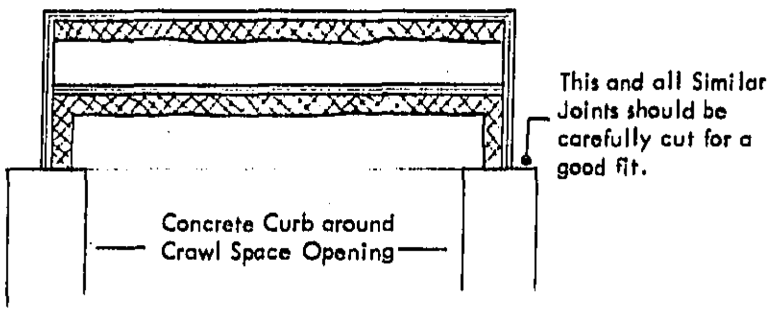


Figure 25: BAFFLE COVER FOR UNDERFLOOR ACCESS OPENING

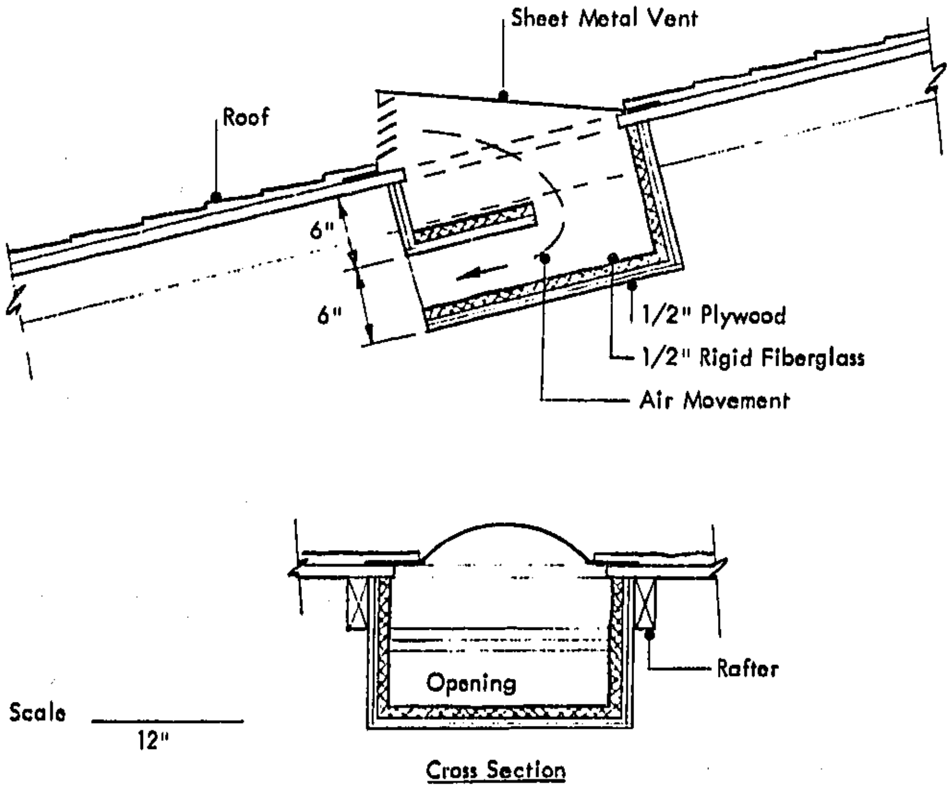


Figure 26: ATTIC VENT BAFFLE

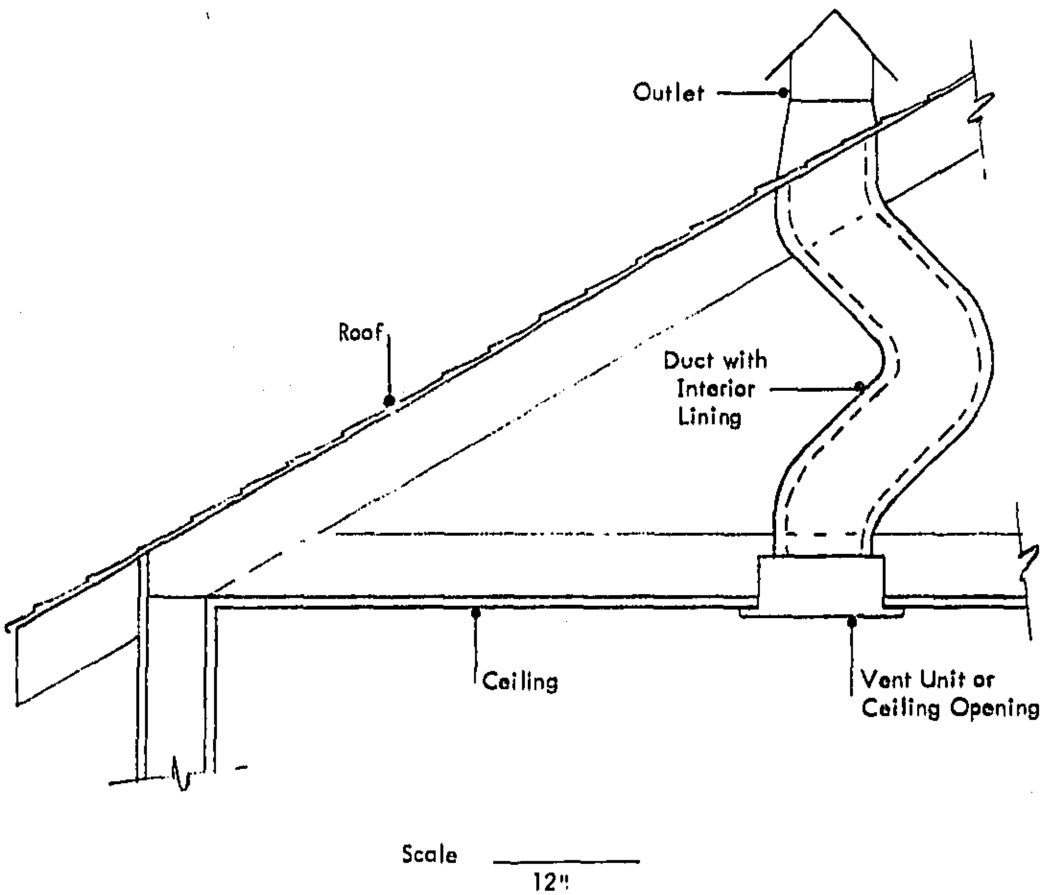
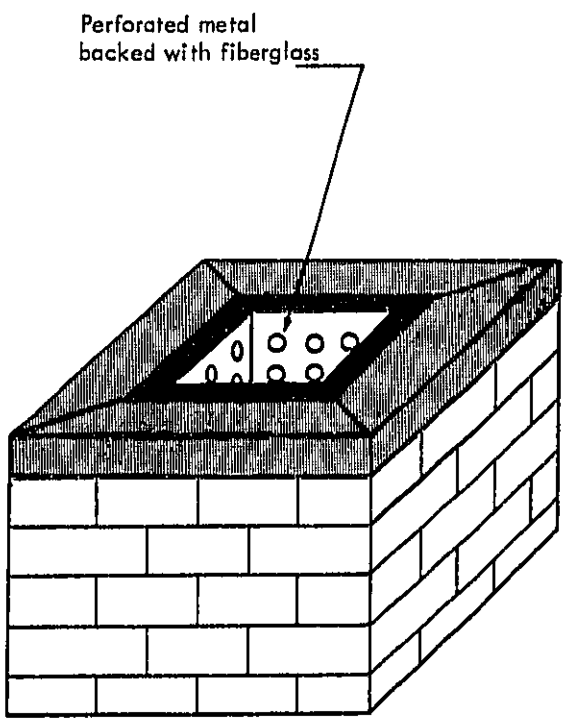


Figure 27: VENT DUCT AT KITCHEN OR BATH



Note: The modification can be slipped into an existing chimney top if sufficiently large, or a new outside surface can be built around the system. The modification is required to be 1 foot in depth.

Figure 28: CHIMNEY MODIFICATION