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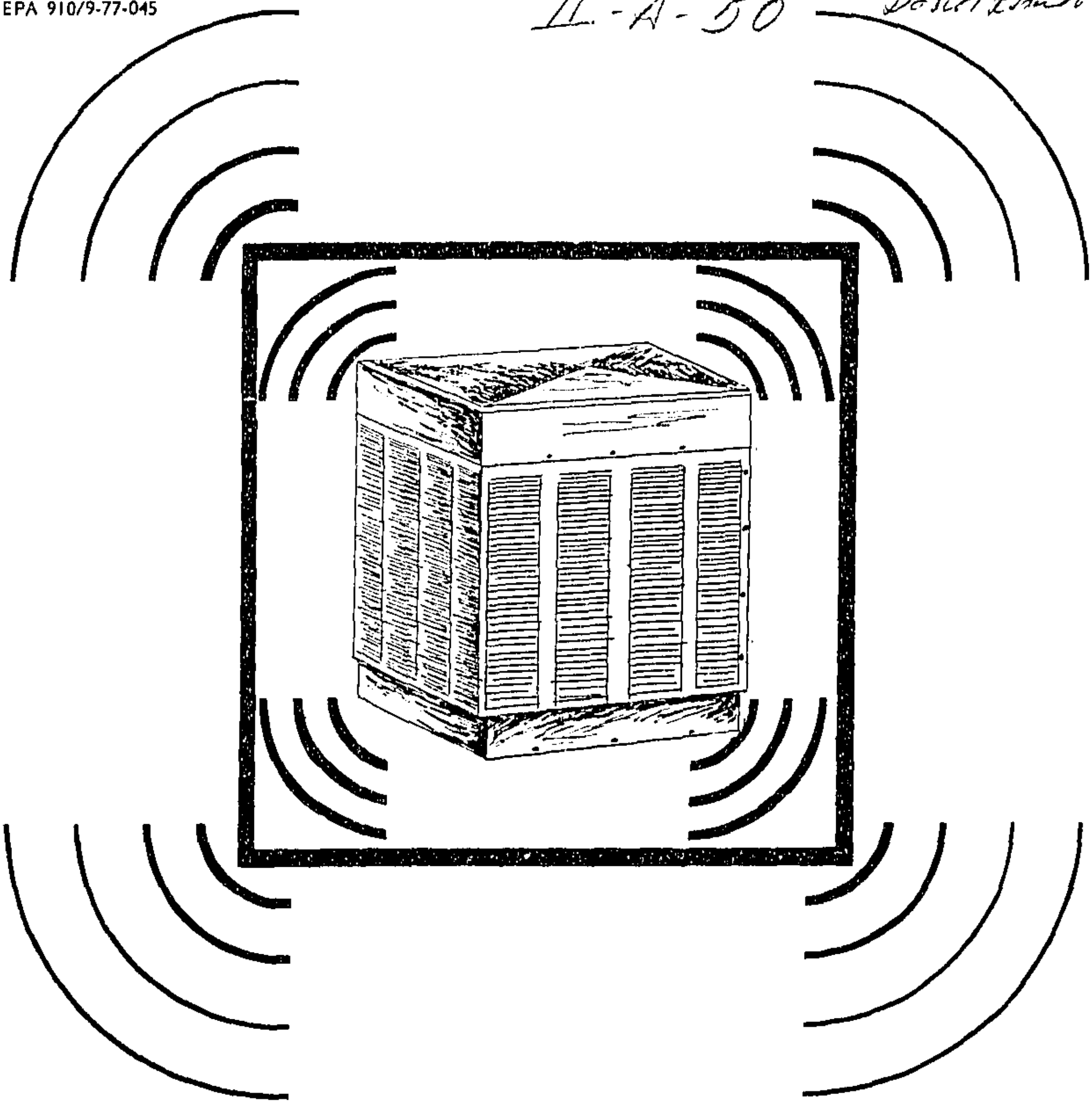

TECHNIQUES FOR CONTROLLING NOISE FROM RESIDENTIAL HEAT PUMPS

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION X NOISE PROGRAM
1200 SIXTH AVENUE
SEATTLE, WASHINGTON 98101

<u>TECHNIQUES FOR CONTROLLING</u>

<u>NOISE FROM RESIDENTIAL HEAT PUMPS</u>

by Dennis G. Ossenkop
Noise Control Specialist

Preface

At the request of the Washington State Department of Ecology Noise Section, the Environmental Protection Agency Region X Noise Program initiated a study to determine methods of reducing the noise impact of residential heat pumps. Two operating four-ton residential heat pumps were located by Mr. Fred Hallum of the General Electric Corporation, Seattle Central Air Conditioning Division office. Permission to construct and measure the acoustic effectiveness of a free standing heat pump enclosure was secured from Mr. William Sullivan of Seattle, Washington. The design and installation of the enclosure was accomplished through the cooperation of Earth Metrics, Inc., Palo Alto, California (under contract to EPA) and EPA Region X Noise Program personnel. Acoustic materials for the free standing enclosure were acquired through Mr. Harvey Britton of E.J. Bartells Company, Renton, Washington. The acoustic effectiveness of a second enclosure was measured at the residence of Mr. Robert Thornton of Gig Harbor, Washington.

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I. Introduction

Pacific Northwest homeowners, like homeowners nationwide, are attempting to reduce their consumption of petroleum and natural gas fuels by installing electric home heating and cooling equipment. One such device is the residential heat pump. Although this device is very miserly with its consumption of electricity, it is generally noisy, in fact, noisy enough to violate state and city noise regulations.

Increasing numbers of these units are being installed, and increasing numbers of noise complaints from neighbors and owners of heat pumps are being voiced. It rapidly became apparent that little information was available about effective noise abatement methods or their cost. With the cooperation of homeowners and the manufacturers of selected units, a study was conducted to determine methods of reducing the noise impact of residential heat pumps.

It is the purpose of this report to present some noise abatement methods that may be used to minimize property line noise levels resulting from operation of residential heat pumps. These methods may be of value in the absence of source noise control measures.

II. Heat Pump Operation and Noise Sources

A heat pump works like a refrigerator or air conditioner. It transfers the heat present in air from one place at a relatively low temperature to another place at a higher temperature.

The heat pump can be used for heating and cooling. When a heat pump is used for heating (Figure 1), cool air outside the building is blown over an even colder outdoor coil. Heat is transferred from the outdoor air to this coil. This heat evaporates the liquid refrigerant in the coil, which is raised above room temperature by compression and then condensed in the indoor coil. By condensing, heat is released and transferred to the indoor air. A fan blows the warm air through ducts to the rooms to be heated.

When a heat pump is used for cooling (Figure 2), the functions of the indoor and outdoor coils are reversed. In this case, heat is absorbed in the indoor coil (thereby cooling and dehumidifying the indoor air) to evaporate the liquid refrigerant which is then circulated through the outdoor coil after having its temperature raised above the outdoor temperature by compression. The refrigerant vapor is then condensed by giving up its heat to the outdoor air circulated over the coil. This is the typical air conditioning process.

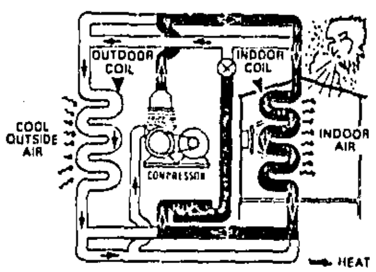


Figure 1.
HEAT PUMP USED FOR HEATING

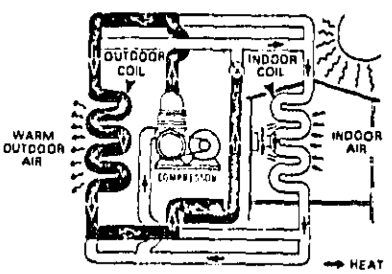


Figure 2.
HEAT PUMP USED FOR COOLING

As can be seen in Figures 1 and 2, there are two major sources of noise, the compressor and the fan. The compressor sounds originate inside the sealed self-contained housing which contains both the electrical motor and the actual fluid pump. Fan related sounds, emitted from the external unit, are generated by the fan blade passing through the air and air flow deflection and turbulence between evaporator coil and deflection grids. Fan sound levels will vary with the number of fan blades, fan RPM, fan diameter, clearance between the fan blades and fan housing, and the rate at which air is being discharged.

Although not a source in itself, case paneling often picks up tones generated by motors, compressor, and fans, particularly when these components are not sufficiently isolated to prevent vibration transmission. The majority of heat pumps currently manufactured are braced and stiffened to mitigate resonance phenomena; however, poor installation and mounting procedures occasionally result in vibration transmission.

III. Procedures to Minimize Heat Pump Noise at the Property Line

A. Placement of Heat Pump on Owner's Property

The fact that the heat pumps produce a constant sound while operating will generally result in the owner placing the unit as far as possible from his or her bedroom or recreational area. This can, and often does, place the unit near the neighbor's bedrooms or recreational areas, thus causing the neighbor to complain about the noise.

Before permanently installing a heat pump, the heat pump installer and the owner of the house should select a location which will minimize the noise impact at nearby property lines. There are several installation locations which should be avoided due to their ability (by providing large reflective surfaces) to increase the noise problem. Described briefly, they are (a) within ten feet of a wall, (b) within ten feet of two adjacent walls (such as a corner) and (c) within fifteen feet of two opposite walls (such as between two houses).

The majority of noise problems resulting from presently installed residential heat pumps would not exist if the installer and homeowner had analyzed the owner's property to determine the location which produced the least noise impact at adjoining properties.

To assist persons in determining the potential noise level at nearby property lines, the Air-Conditioning and Refrigeration Institute (ARI)[1] has developed a Sound Rating Program. This program is a manual/graphical procedure which provides a means of determining the property line noise level of a heat pump <u>before</u> it is installed. The procedure requires the Sound Rating Number (available from ARI) of the proposed heat pump and the distances from the proposed site of the heat pump to the noise sensitive property lines. Appendix A presents elements of the Program plus several example calculations. In Washington State and Portland, Oregon, the maximum permissible nighttime noise level at a residential property line is 45 dBA.

If, after the above noise analysis has been completed, the unit would be in violation of local noise regulations, both the installer and homeowner should consider placing the unit within a sound reducing enclosure.

[1] Air-Conditioning and Refrigeration Institute, 1815 North Fort Myer Drive, Arlington, Virginia 22209

B. Enclosure Design and Noise Reduction Effectiveness

Performing a property line noise evaluation using the ARI Sound Rating Program will provide the heat pump installer and homeowner with a very close approximation of the predicted noise level. If, after locating a site which yields the least noise impact, the property line sound level is still above the applicable nighttime standard, an enclosure should be considered.

Two different types of heat pump enclosures were studied. Both enclosures are installed around operating four-ton residential units with air inlets on four sides and a vertical discharge.

Although both study enclosures were placed around vertical discharge heat pumps, the concepts, acoustical results, and construction materials can be applied to other heat pump configurations.

Choice of construction materials and attention to assembly detail are important factors in order to achieve acceptable results. The materials utilized in the enclosure study consisted of:

- 3/4-inch Exterior Grade A/C Plywood
- 2-inch thick Acoustic Fiberglass Duct Liner
- 1/4-inch Acoustic Foam Gasket Material
- Assorted 2-inch x 4-inch and 2-inch x 2-inch Fir Frame Stock
- Assorted Screws and Fasteners
- Silicone Sealant

Grade A/C 3/4-inch plywood was selected to provide adequate mass for low frequency sound attenuation and to provide an exterior surface such that the owner could paint or otherwise finish the exterior of the enclosure.

Acoustic fiberglass duct liner was chosen for its acoustic properties, availability, and its acoustically transparent face sheet. The open fiber side of the duct liner blanket is placed against the interior side of the enclosure with the firm black face sheet facing the heat pump and air flow. Attachment to the plywood walls is provided by using mechanical fasteners which generally can be purchased from the fiberglass supplier. Other brands of acoustic fiberglass duct liner will work equally well; however, common house wall or ceiling insulation should not be used as its acoustic properties are generally not known. Containment of fiberglass house insulation is very difficult as it does not utilize an acoustically transparent face sheet.

Foam gasket material is required to provide an acoustically tight seal between adjacent panels of the enclosure. All enclosure designs must provide access to the heat pump for service, therefore some of the enclosure panels can not be permanently sealed with silicone sealant. The gasket material is glued in place where panels and frames come together.

Several construction-assembly details should be remembered when designing and building an enclosure:

1. Make certain there are no cracks or holes in the enclosure walls (between panels or at the intersection of panels at corners). Gasket material or silicone sealant application will prevent "sound leaks".

2. Panels should be "floating" on a foam gasket material such that panels do not make physical contact with each other or the frames (except through mounting screws).

3. Fasten the fiberglass duct liner securely on 12-inch centers using wood screws through washers or a nail driven through a 2-inch square piece of sheet metal. (See Figure 10.)

4. The enclosure must not touch the heat pump; otherwise heat pump case noise will be transmitted to the enclosure, then into the air.

5. Provisions must be designed into the enclosure to provide flow separation between inlet air and discharge air. (See Figure 4) This provision is usually necessary to eliminate or reduce air recirculation which results in lost efficiency.

6. The enclosure should include a roof of some type to eliminate water penetration (from rain) into the fiberglass.

Enclosure A - FREE STANDING

General Description

A free standing enclosure was constructed from 3/4-inch exterior grade plywood attached to a frame constructed from fir 2" x 4" studs. The enclosure was designed to allow incoming air to enter on all four sides at the base of the enclosure. This basic enclosure yielded an average sound level reduction of approximately 5 dBA. An additional 2 dBA reduction was achieved by lining the inside of the enclosure with 2-inch thick acoustic fiberglass duct liner. The cost of materials was approximately $165.00. Construction time is approximately 20 hours. Building details are shown in Figures 4 through 12.

Acoustic Results

Acoustic data were gathered at four locations near the unit for each of the three configurations: (a) Baseline (operating heat pump with no enclosure), (b) 3/4-inch thick plywood enclosure, and (c) 3/4-inch thick plywood enclosure with an inner liner of 2-inch fiberglass duct liner. Figure 3 illustrates the general layout of the test site and the location of the sound measurement points. Table 1 presents a tabulation of the measured data and attenuation values between successive configurations. Permanent objects, such as trees, walls or stairs located within 10-15 feet of the test heat pump were typical of most residential heat pump installations; therefore, one should expect similar results from enclosures constructed at other sites.

Enclosure B - ATTACHED TO HOUSE WALL

General Description

Acoustic measurements were taken at the home of a heat pump owner who had constructed his own enclosure. This design was developed by a California based consultant and consists of a house-like structure which is closed on three sides and completely open on the fourth. The roof is sloped at a 45° angle away from the noise sensitive property line. Figure 13 presents a general diagram of this enclosure. A double wall of 3/4-inch plywood was built around a 2" x 2" stud frame. The roof was also of 3/4-inch plywood. The heat pump is positioned within the enclosure to allow inlet air to enter from the open side of the enclosure and circulate around the base of the heat pump. Discharge air is blown out the top of the unit and deflected (by the 45° roof) away from the noise sensitive property line. This enclosure is also lined with acoustic fiberglass duct liner.

Acoustic Results

Acoustic data were gathered at six locations on three sides of the test enclosure. A general layout of the measurement points and acoustic results are shown in Figure 14. Variation in the attenuation values at points C, D, E, and F are attributed to reflections off the large roof overhang above the unit. Differences in house structure, unit location, and enclosure construction techniques may result in different levels of noise reduction. From Figure 14, it can be seen that the noise attenuation resulting from this enclosure is very directional. When considering this type of enclosure, care must be exercised to prevent degradation of the property line noise level on the discharge side of the enclosure.

C. Heat Pump Compressor and Fan Sound Reduction Methods

CAUTION: The following procedures, if utilized, should be performed by the heat pump installer.

Compressor Sound Reduction

As stated in Section II, there are two primary sound sources within a heat pump: the compressor and the fan.

A method has been tested, on a four-ton unit, which yielded an 8.5 dBA reduction in the compressor sound level. The compressor treatment consisted of wrapping the compressor housing with two inches of fiberglass acoustic duct liner, followed by the factory compressor sound shroud, which was covered with one inch of fiberglass duct liner, followed by a layer of one pound per square foot density lead. Figure 15 indicates the materials utilized and order of application. The heat pump on which this method was tested is supported by four points which are in contact with a concrete mounting slab. The compressor sound level component was reduced an additional 1.5 dBA by setting the entire heat pump unit on a 1-inch thick sheet of rigid styrofoam, thereby eliminating vibration of the case bottom which supports the compressor.

These two sound treatments should not reduce the unit's efficiency as the compressor is cooled by the passage of refrigerant. These compressor treatments have, in many cases, reduced the compressor sound to a level where complaints have ceased.

Fan Sound Reduction

Experimentation with various fan blade configurations and motor speeds, on a four-ton unit, has yielded fan noise level reductions of up to 6 dBA at the property line. Table 2 indicates the limited number of combinations tested and their property line sound levels.

The sound reduction effectiveness of a centrifugal or drum fan was evaluated on an operating four-ton heat pump. The original fan and motor were removed and replaced with a housing containing a 15-inch diameter - 15-inch wide drum fan which rotated at 458 rpm. The data shown in Tables 3 and 4 indicate between a 2 dBA and 14 dBA fan sound reduction depending on the direction of discharge flow. Sound reductions for the total unit operating with the centrifugal fan range between 2 dBA and 9 dBA, again, depending on the direction of discharge flow. The cost of the centrifugal fan assembly could range from $250 to $400, depending on unit size and manufacturer.

IV. Summary

This investigation into noise generated by residential heat pumps can be summarized in a two-step procedure for preventing or eliminating property line noise complaints created by heat pumps. The procedure consists of a) evaluation of unit location and b) selection of noise abatement technique. The techniques presented provide the following approximate amounts of total unit sound reduction.

1.	Free Standing Enclosure	:	7 dBA
2.	Enclosure Attached to Wall	:	3 dBA - 16.5 dBA
3.	Compressor Treatment Only	:	3 dBA
4.	Fan Change Only (No. of Blades, rpm)	:	1 dBA - 2 dBA
5.	No. 3 and 4 Combined	:	7.5 dBA
6.	Centrifugal Fan	:	2 dBA - 9 dBA
7.	No. 3 and 6 Combined	:	4 dBA - 11 dBA

GENERAL LAYOUT OF FREE-STANDING HEAT PUMP ENCLOSURE TEST SITE

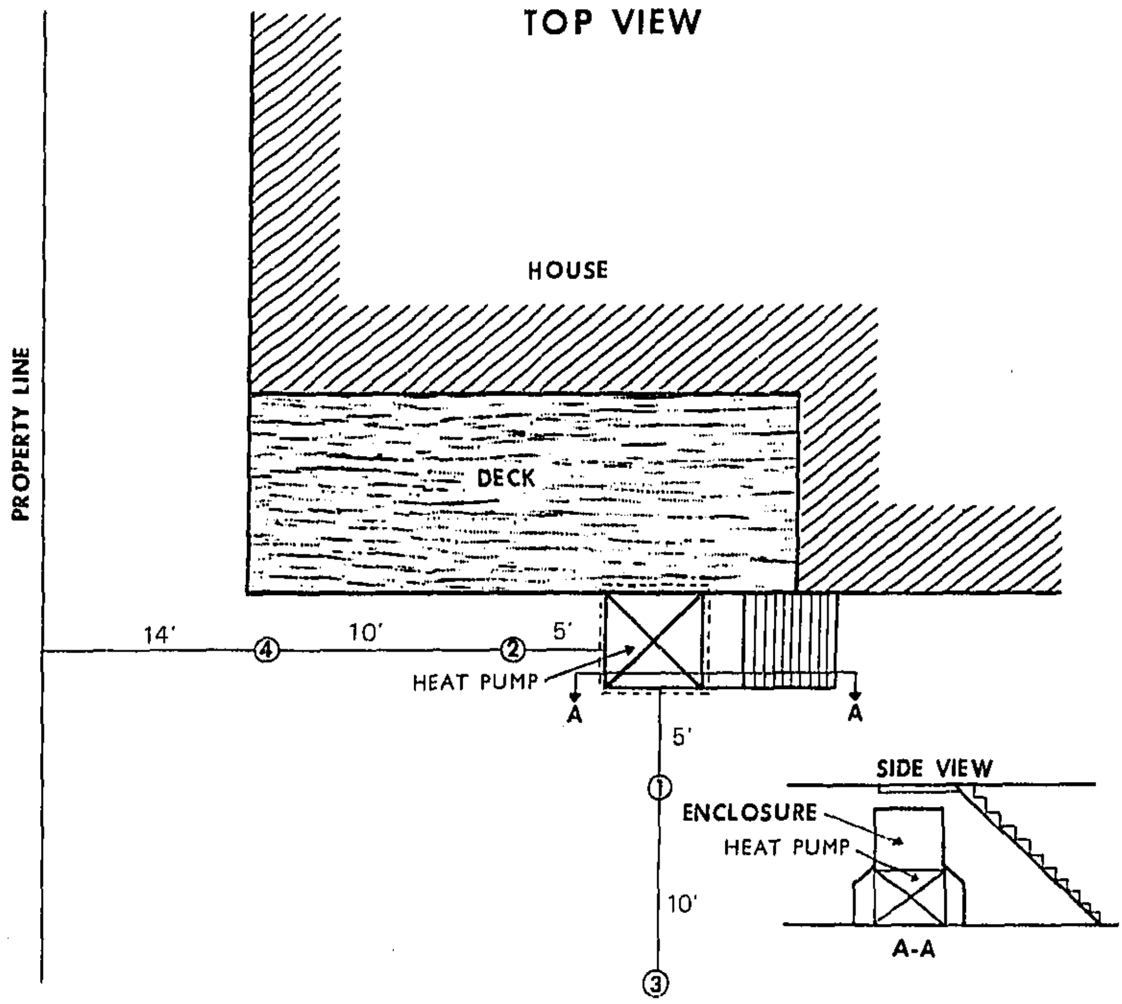


FIGURE 3

NOTE: UPPER 2 PANELS
ON 2 SIDES
OMMITTED FOR CLARITY.
SEE SECTION DRWS
FOR ACTUAL LOCATIONS.

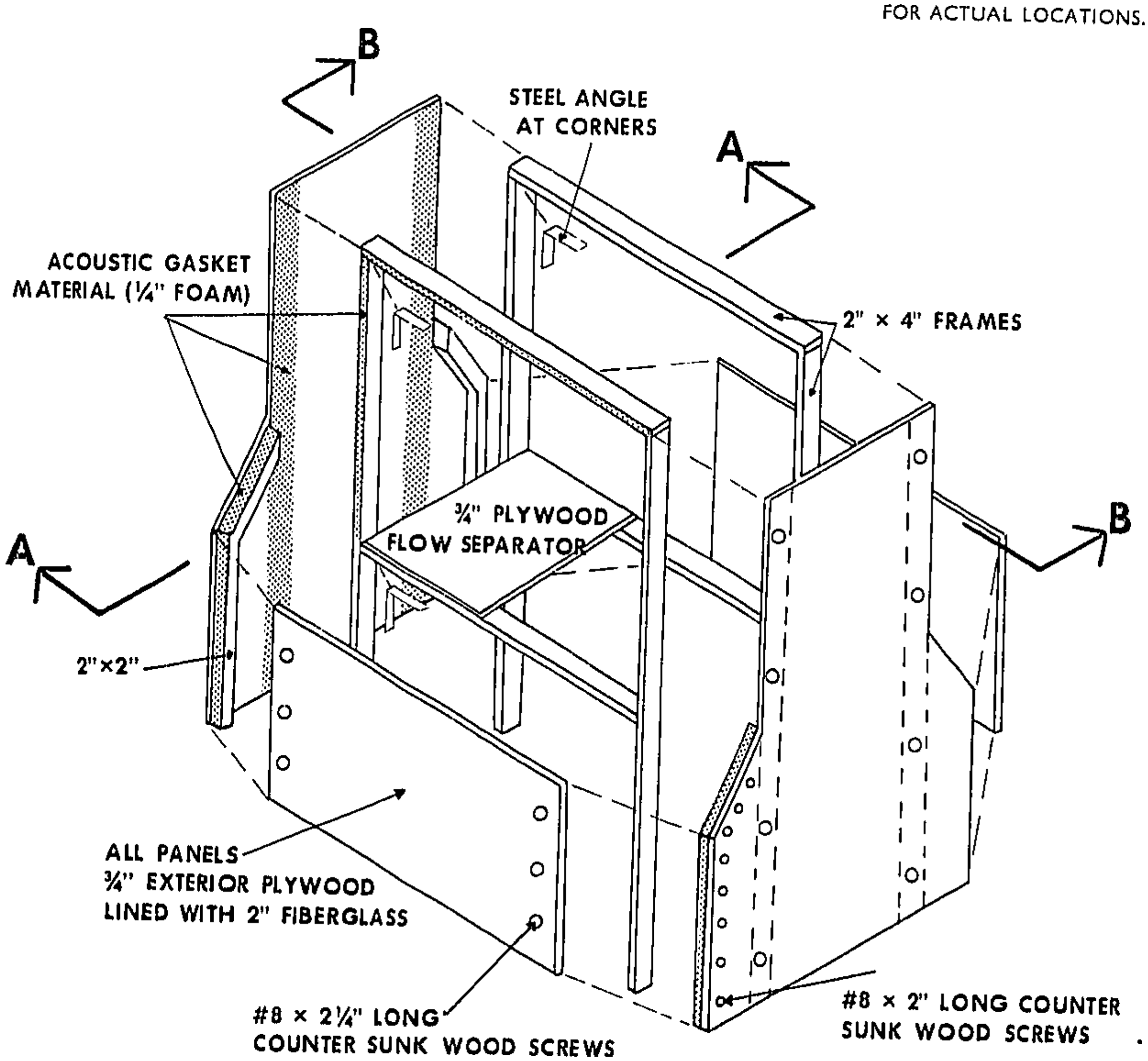
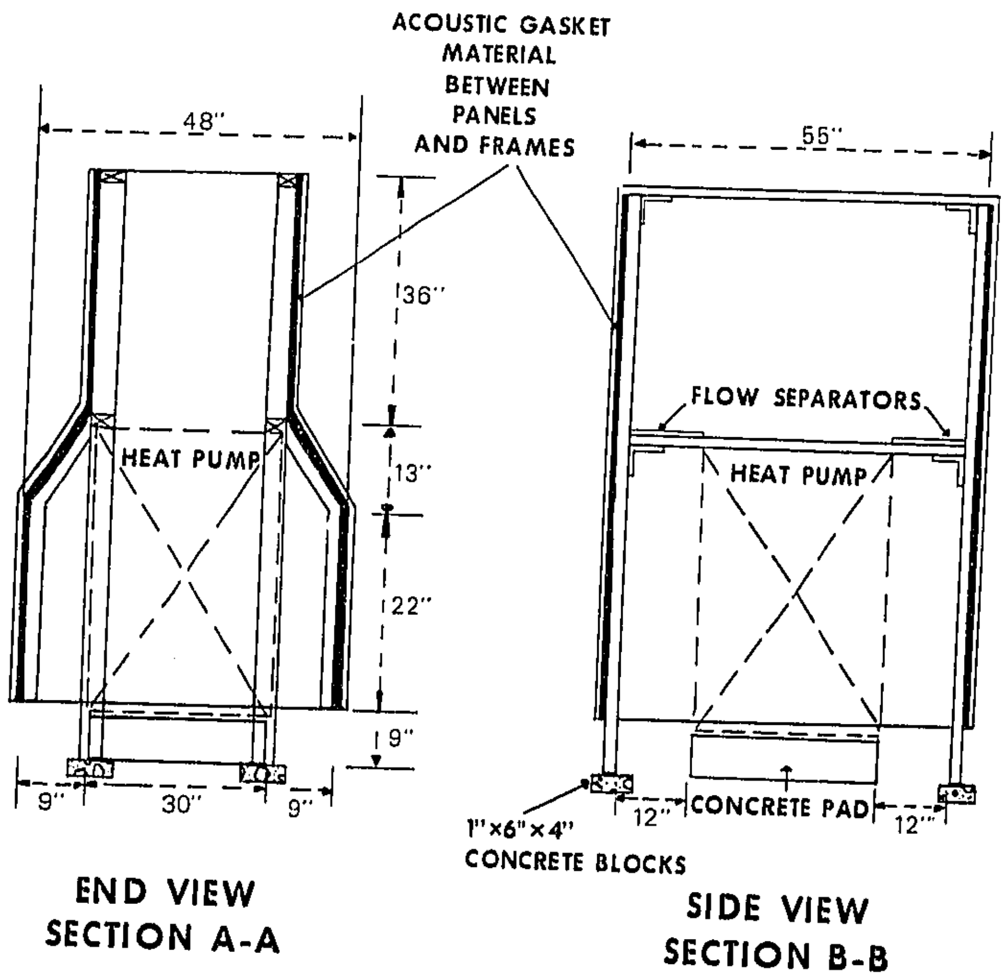


FIGURE 4



ACOUSTIC GASKET
MATERIAL
BETWEEN
PANELS
AND FRAMES
48"
36"
13"
22"
9"
HEAT PUMP
9"
30"
9"
55"
FLOW SEPARATORS
HEAT PUMP
12"
CONCRETE PAD
12"
1"×6"×4"
CONCRETE BLOCKS
END VIEW
SECTION A-A
SIDE VIEW
SECTION B-B

FIGURE 5

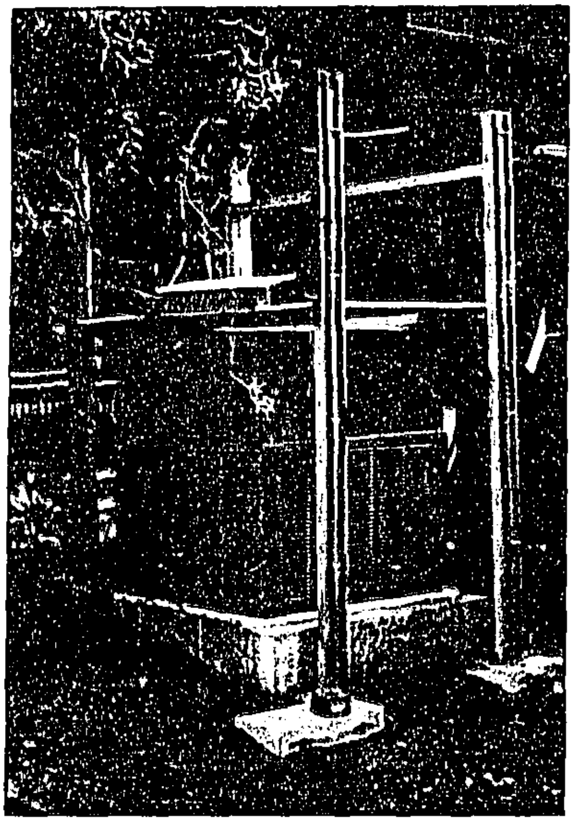


Figure 6 Heat Pump Unit and Enclosure Frame

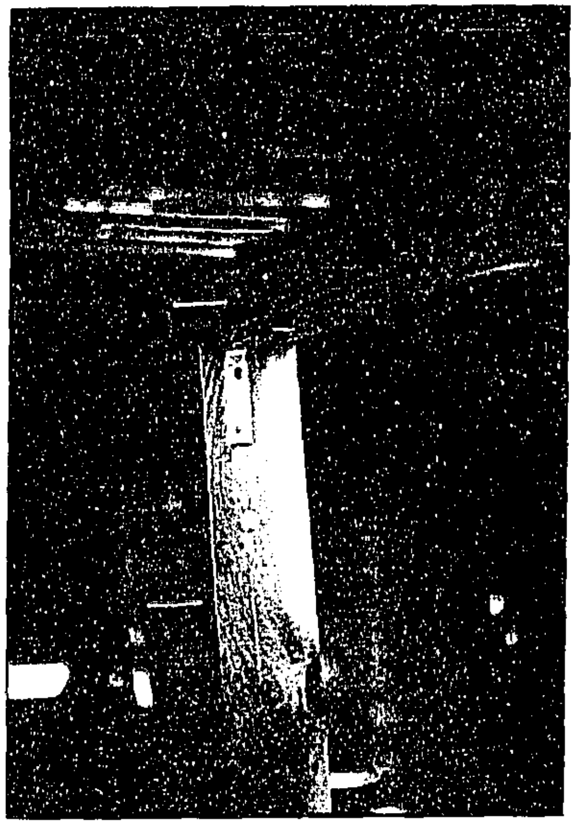


Figure 7 L-Bolt Junction and Weather-stripping.

United States
Environmental Protection
Agency

June 1977

EPA

JET ROAR

The jet age took off with a roar in the late 1950's. The U.S. today has more than 450 major airports serving an American fleet of some 2,200 large jets and thousands of smaller aircraft. Ironically, the very success of the air transportation industry has come to cloud its future.

The unwanted sound of airport and aircraft operations is seriously depressing the quality of life of millions of Americans. The problem is one of technology, flight scheduling, and land use planning.

JET ROAR, a new film from EPA, examines this problem from an environmental perspective. It reports on the battle against jet age noise, a battle being pressed in many American communities by airports and air carriers, by pilots, planners, and people who live in neighborhoods surrounding some of our busiest air centers.

The film's message is this: We *can* do something about aviation noise. And in cities such as Seattle, Minneapolis-St. Paul, and Boston, people *are* doing a lot about it.

JET ROAR was produced for the U.S. Environmental Protection Agency by Richter McBride Productions, Inc., and written and directed by Robert McBride.

Jet Roar

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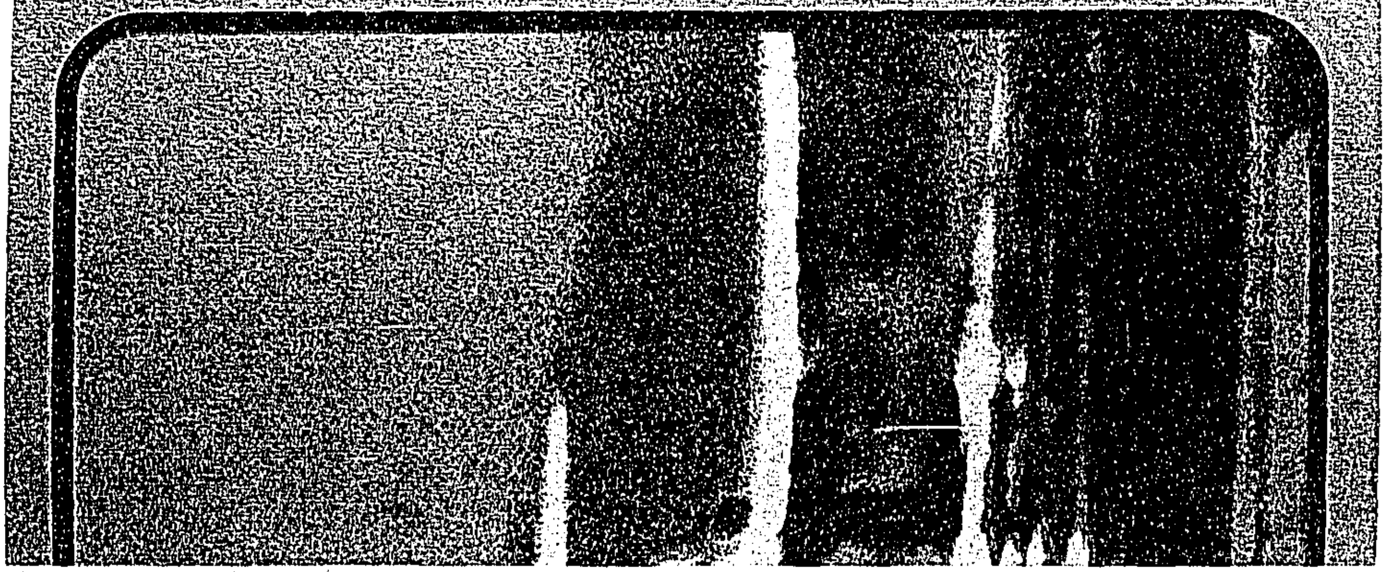

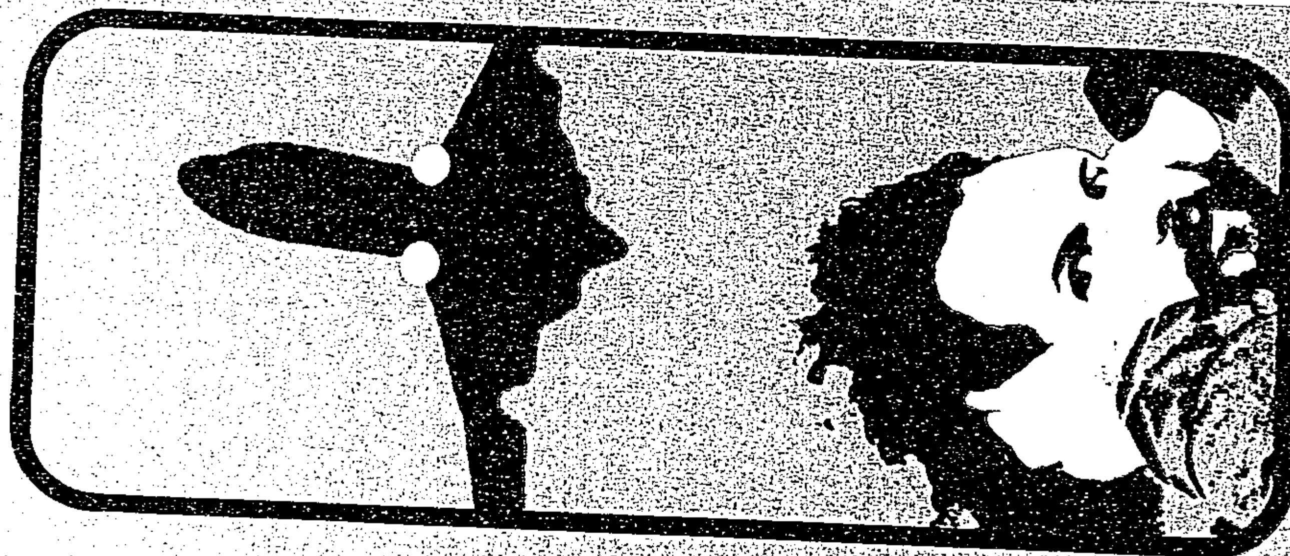

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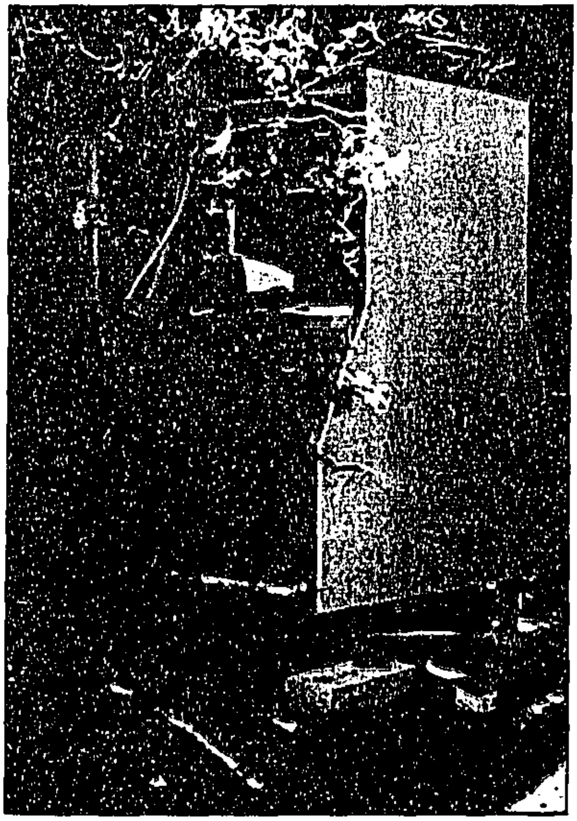


Figure 8 Front Panel on Frame

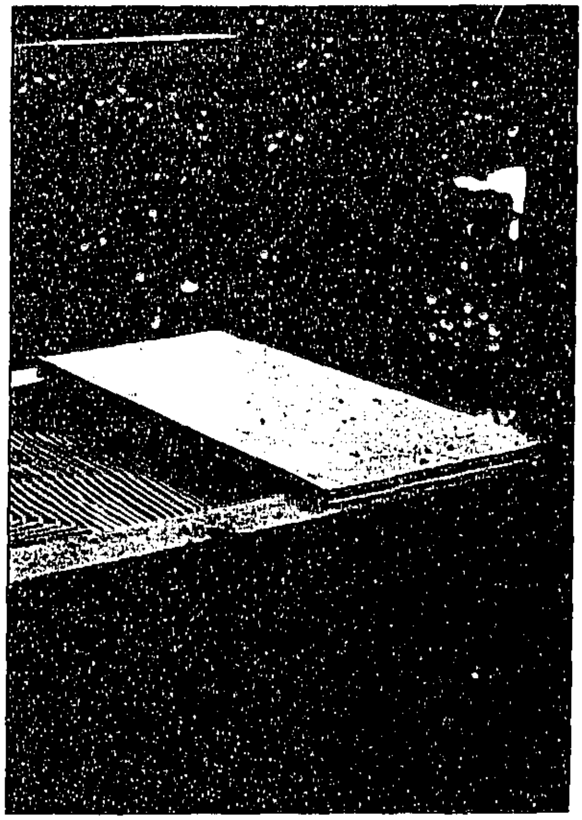


Figure 9 Design Measures to Prevent Recycle of Exhaust Air.

Figure 10 Glass Fiber Acoustic Material
Fastened to Plywood Panel.

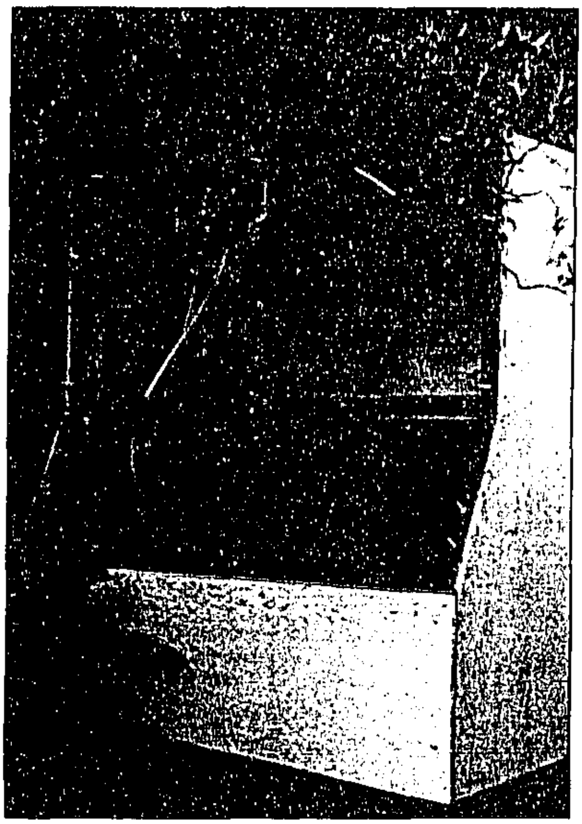


Figure 11 Completed Heat Pump Enclosure, Minus Two Side Panels

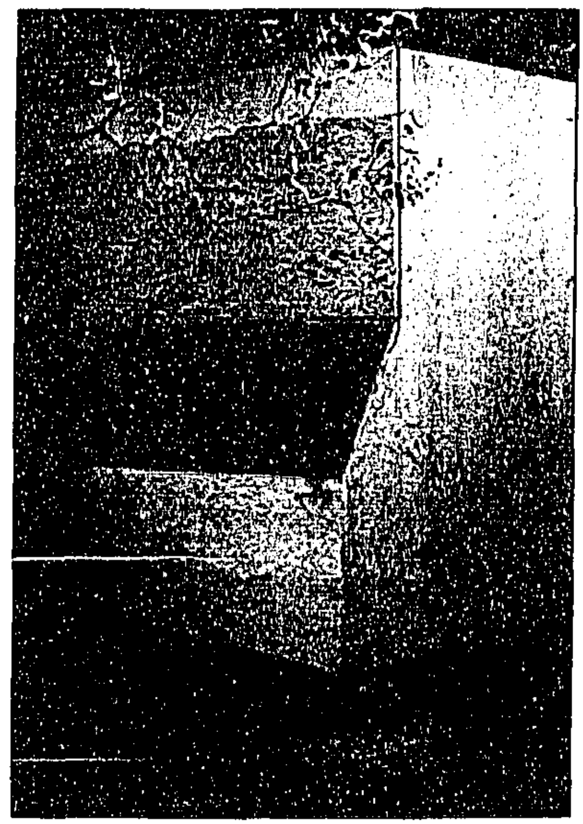


Figure 12 Completed Heat Pump Enclosure, Minus Single Side Panel

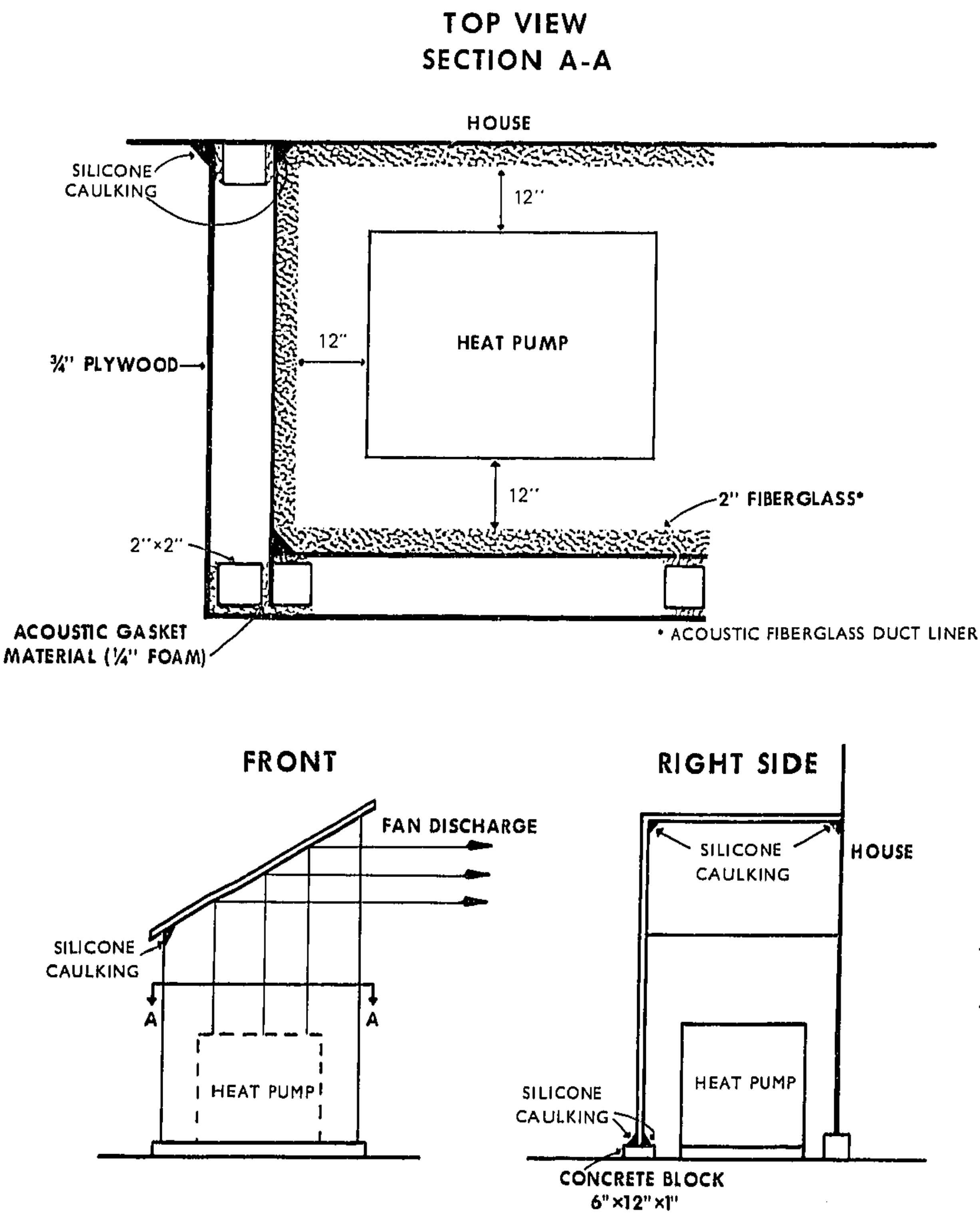
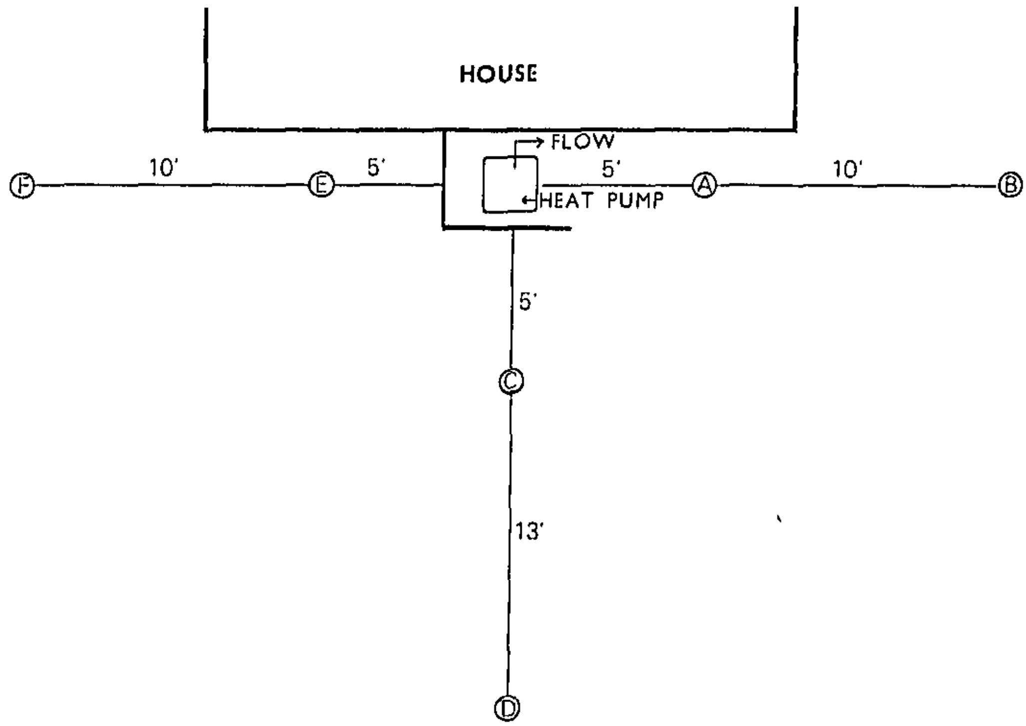

TOP VIEW
SECTION A-A
HOUSE
SILICONE CAULKING
12"
HEAT PUMP
¾" PLYWOOD
12"
12"
2" FIBERGLASS*
2"×2"
ACOUSTIC GASKET MATERIAL (¼" FOAM)
* ACOUSTIC FIBERGLASS DUCT LINER
FRONT
FAN DISCHARGE
SILICONE CAULKING
A
A
HEAT PUMP
RIGHT SIDE
SILICONE CAULKING
HOUSE
HEAT PUMP
SILICONE CAULKING
CONCRETE BLOCK 6"×12"×1"

FIGURE 13

TEST SITE GENERAL LAYOUT
TOP VIEW

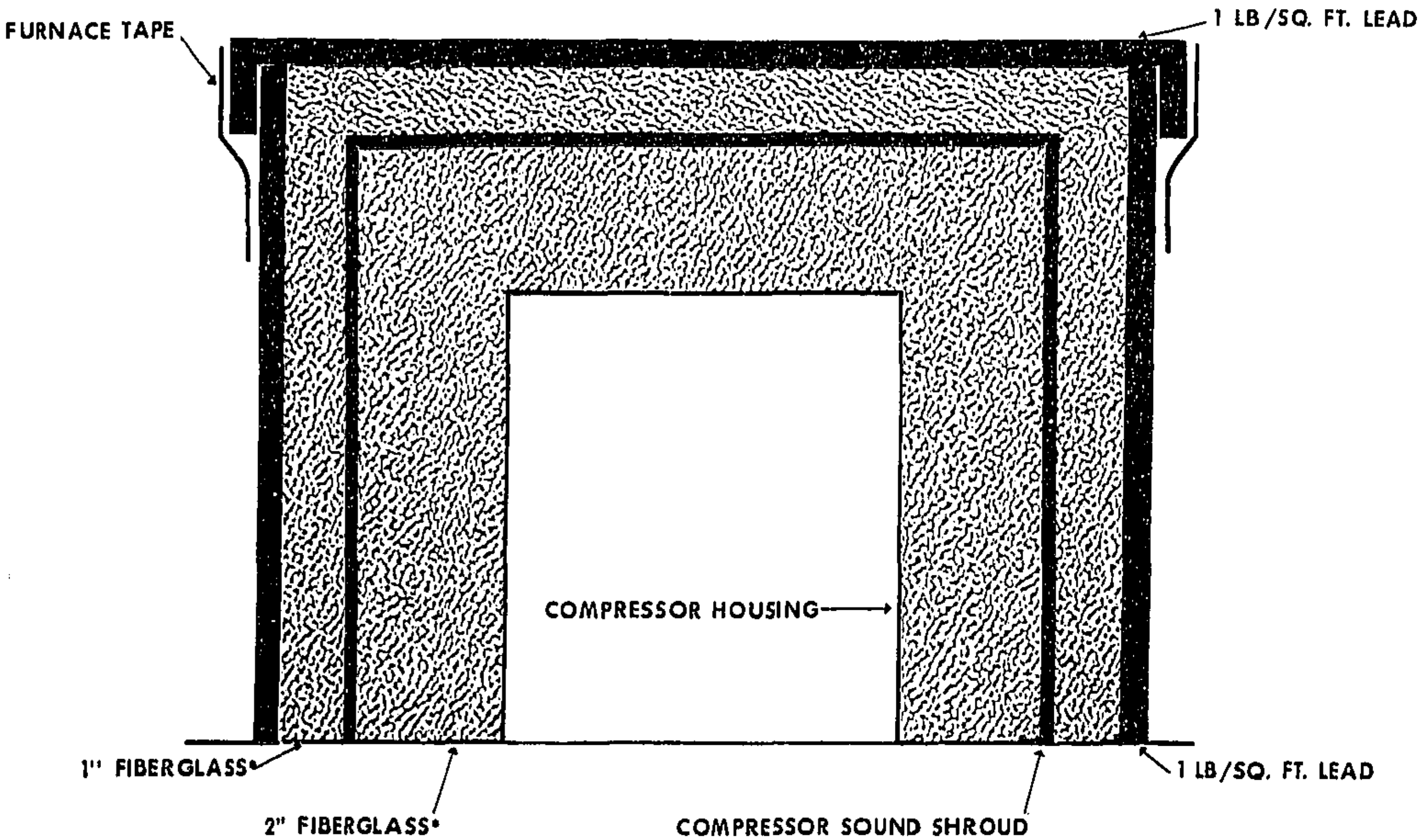


ACOUSTIC RESULTS

POSTITION	SOUND LEVEL -dBA NO ENCLOSURE	SOUND LEVEL -dBA WITH ENCLOSURE	ATTENUATION -dBA
A	65	65	0
B	62	59	3
C	65	53	12
D	61	47.5	13.5
E	65	50	15
F	62	45.5	16.5

FIGURE 14

CROSS SECTION OF COMPRESSOR SOUND CONTROL TREATMENT



* ACOUSTIC FIBERGLASS DUCT LINER

FIGURE 15

Table 1

Tabulation of Enclosure Sound Attenuation

Configuration

Sound Measurement Location	Sound Measurement Distance	Baseline Sound Level dBA	Δ dBA	Plywood Enclosure dBA	Δ dBA	Plywood Enclosure with 2" Fiberglass dBA	Total Δ from Baseline
1	5' Front	59	- 5.5	53.5	- 1.7	51.8	- 7.2
2	5' Left	61.8	- 5.8	56	- 1.7	54.3	- 7.5
3	15' Front	51.5	- 3.5	48	- 1.8	46.2	- 5.3
4	15' Left	53.5	- 4.0	49.5	- 2.5	47	- 6.5
Average Attenuation			- 4.7		- 1.9		- 6.6

Table 2

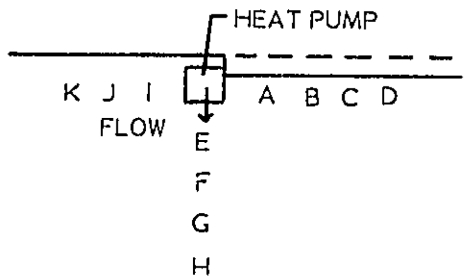
Fan Sound Component Reduction
on A General Electric 4 ton Heat Pump

Number of Blades	Fan Diameter Inches	Fan Pitch Degrees	Motor RPM	Sound Level At Property Line (29 FT) dBA
3*	22	34	1075	56
4	22	25	1075	54
4	22	35	825	53
3	22	35	825	50

* Stock fan on a General Electric 4 ton Heat Pump

TABLE 3

HEAT PUMP FAN COMPONENT AND TOTAL UNIT SOUND REDUCTIONS WITH CENTRIFUGAL FAN FLOW PERPENDICULAR TO HOUSE WALL

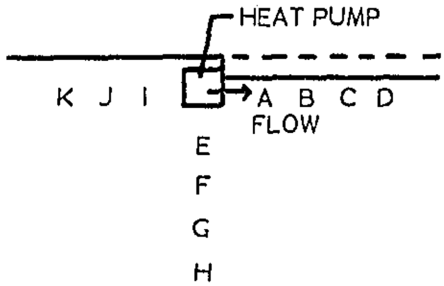


LOCATION	DISTANCE FT.	STOCK FAN* dBA	CENTRIFUGAL** FAN dBA	FAN SOUND REDUCTION dBA	TOTAL UNIT (STOCK FAN) dBA	TOTAL UNIT (CENT. FAN) dBA	TOTAL UNIT REDUCTION dBA
A	5	71.5	61.	10.5	72.	67.5	4.5
B	10	66.5	57.	9.5	67.	58.	9.
C	15	63.5	54.5	9.	64.	57.	7.
D	20	61.5	52.	9.5	62.5	55.	7.5
E	5	71.	68.	3.	71.5	68.5	3.
F	10	65.	63.	2.	65.5	62.	3.5
G	15	61.	59.	2.	62.5	59.	3.5
H	20	60.	57.	3.	61.5	57.5	4.
I	5	71.	60.	9.	72.	65.	7.
J	10	65.5	57.	8.5	67.	58.	9.
K	15	62.	53.	9.	63.	55.	8.

* 3 Blade, 35° Pitch, 1075 rpm
** 15 inch dia., 15 inch wide, 458 rpm

TABLE 4

HEAT PUMP FAN COMPONENT AND TOTAL UNIT SOUND REDUCTIONS WITH CENTRIFUGAL FAN FLOW PARALLEL TO HOUSE WALL



LOCATION	DISTANCE FT.	STOCK FAN* dBA	CENTRIFUGAL** FAN dBA	FAN SOUND REDUCTION dBA	TOTAL UNIT (STOCK FAN) dBA	TOTAL UNIT (CENT. FAN) dBA	TOTAL UNIT REDUCTION dBA
A	5	71.5	66.	5.5	72.	66.	6.
B	10	66.5	64.	2.5	67.	64.	3.
C	15	63.5	61.	2.5	64.	62.	2.
D	20	61.5	58.5	3.	62.5	60.	2.5
E	5	71.	60.	9.	71.5	64.	7.5
F	10	65.	55.5	9.5	65.5	58.5	7.
G	15	61.	53.5	7.5	62.5	56.	6.5
H	20	60.	52.	8.	61.5	55.5	6.
I	5	71.	57.	14.	72.	67.	5.
J	10	65.5	53.	12.5	67.	60.	7.
K	15	62.	50.	12.	63.	56.5	6.5

* 3 Blade, 35° Pitch, 1075 rpm
** 15 inch dia., 15 inch wide, 458 rpm

APPENDIX A

APPLICATION OF THE ARI SOUND RATING PROGRAM

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The ARI Sound Rating Program provides a method for determining the *predicted* noise level for unitary air conditioning and heat pump equipment.

The ARI sound rating system is based on a sound rating number – referred to as an SRN. Sound rating numbers are determined by testing each unit in a special acoustical sound chamber. The SRN scale normally ranges from 15–24. The lower the number, the quieter the unit.

These numbers are being listed in a separate section of the ARI Directory. Spec Data Sheets will include the SRN's when units are certified.

This introductory manual provides a step-by-step procedure for predicting outdoor sound levels – produced by air conditioning equipment. Topics covered include: equipment location, barrier shield, sound path and distance factors – plus sample problems and tables.

DEFINITION OF TERMS

Sound Rating Number – SRN. That number assigned to outdoor unitary equipment rated in accordance with *ARI Standard 270-67* at standard rating conditions. (80°F db/67°F wb indoors – 95°F db outdoors, with rated air flow.)

Sound Level Number – SLN. The result of applying the three basic factors to the SRN. These factors are – location, barrier shield and sound path.

Decibel – dB. The basic unit of measurement used in acoustics. Technically it is ten times the logarithm of the ratio of a measured sound to a reference sound – i.e.

$$dB = 10 \log_{10} \frac{\text{Measured Sound}}{\text{Reference Sound}}$$

"A" Scale or dBA. The decibel level as measured on the "A" scale of a sound level meter. This scale closely approximates the response characteristics of the human ear. "B" & "C" scales have a higher frequency range reception.

Ambient Noise. Surrounding or background noise of a given environment.

Sound Level Meter. An instrument used for direct measurement of sound pressure levels. Scales usually include dBA, dBB & dBC. Measurements should be taken no closer than 3 feet to any reflective surface including ground level.

Equipment Location Factor. This factor considers the effect of walls and reflective surfaces other than surface on which unit is installed. It is the only factor that is *added* to the sound rating number.

Barrier Shielding Factor. Barriers, when effectively used, contribute considerably to the reduction of noise level. Such a barrier may be the corner of a building, parapet or a wall. Determine the shielding factor by using distances around or over the barrier. It is *deducted* from the SRN.

Sound Path Factor. This factor adjusts for the path of sound from the unit to the point of evaluation. It may be to the outdoors, to a room through open or closed windows or through a wall. It is *deducted* from the SRN. In most applications the factor will be zero – or to point outdoors.

Distance Factor. The fourth factor to be considered is the direct distance from the equipment to the point of evaluation. It is used, along with the SLN, to predict the dBA in the nomograph (Table 1, page 11).

The balance of this manual contains a series of sample problems and worksheets – designed to acquaint you with most types of sound applications.

The worksheets are easy to follow with step-by-step procedures that guide you to the answer quickly and accurately.

Always keep in mind, when working with sound reduction, that doubling the distance from the noise source to the point of evaluation reduces the sound level by 6 decibels.

As an example, if the sound level is 64 dBA, at 8 feet, then at 16 feet the sound level is reduced to 58 dBA. However, if the noise source is reduced one-half, the sound level is reduced by only 3 decibels.

From this example, it can be seen that it is more advantageous to place the unit as far from the property line or point of evaluation as possible.

Narrow, or small side yard location installations are not recommended.

Shrubbery and other light screens and fences are of little value in reducing radiated sound. However, equipment which is not visible may be psychologically more acceptable – even though sound levels are no different. This is an important consideration and can be used as an advantage, if properly applied.

Here are some typical questions and answers frequently asked about sound and its measurements.

Q. When an outdoor source produces a sound level of 60 dBA at a distance of 15 feet, what will be the level at (a) 30 feet; (b) 7½ feet?

A. (a) 54 dBA (b) 66 dBA. Doubling the distance reduces the sound level by 6 dBA.

Q. What is a generally acceptable sound level in a bedroom?

A. 40 dBA.

Q. What sound level does a typical outdoor air conditioning unit produce at a distance of 15 feet from unit?

A. 58 dBA, plus or minus 5 dBA.

Q. What difference in sound level must be registered before the average person thinks the change is twice as loud?

A. 10 dBA.

Q. What change in sound level has to be made before the human ear can detect it?

A. From 3–5 dBA. On the average, it takes a 3 dBA change for persons to notice a difference. A 5 dBA change will alter the reaction for people to say that it is definitely better or worse.

Q. What can be done to reduce the noise level from outdoor air conditioners?

A. Proper equipment location or the use of solid walls and barriers. Select a location as far away as possible from areas where noise is "unwanted".

SAMPLE EXERCISES

Problem Set 1 — There are three individual problems in this set (A, B and C). Problem A, however, consists of Part 1 and Part 2 to dramatize the significance of adding a barrier, using the same conditions.

Problem A — Part 1

Determine Sound Rating Number (SRN) from either ARI Directory or manufacturer's spec sheets. Enter result on line 1 (we'll assume 19 to be SRN).

Find Equipment Location Factor from Reference Guide (Figure 1, page 8). Unit is installed within 10 feet to reflective surface of building. Select "B" from chart on Figure 1. Factor is 1. Enter 1 on line 2 of worksheet.

Add lines 1 & 2. Enter total — 20 on line 3.

Determine Barrier Shield Factor — No barrier shield in this example. Enter "0" on line 4 of worksheet.

Sound Path Factor — See page 10. The evaluation is to *a point outdoors* (Path A). Enter factor "0" on line 5. Total lines 4 & 5. In this example it's "0".

Sound Level Number — Subtract line 6 from line 3 (20 – 0 = 20) SLN is 20. Find distance from unit to evaluation point. (From plot plan or installation sketch.) In this example it is 15 feet.

Now that the SLN is known — 20, and the distance factor is known — 15, plot the SLN on left hand side of nomograph (Table 1, page 11) as shown. Plot distance factor on right hand side. Connect points using ruler. The point at which line crosses center scale is the predicted dBA level.

Result for this example — 62 dBA. In most cities this level will be above limitations. Two choices are available; either the unit must be relocated or a barrier must be added. Continue with part 2 of problem below to show effect when barrier is added.

Problem A — Part 2

Adding a barrier wall changes two factors in this part of the problem. These two factors are the barrier shield and equipment location. Keep in mind that adding a barrier wall or unit relocation should not be done *until* a worksheet and sketch has indicated that an acceptable range of sound level can be achieved.

Lines 1, 5 & 8 remain the same.

Line 2 becomes a factor of "2" because of the two opposite reflective surfaces. (The barrier wall and the wall next to unit are less than 15 feet apart.)

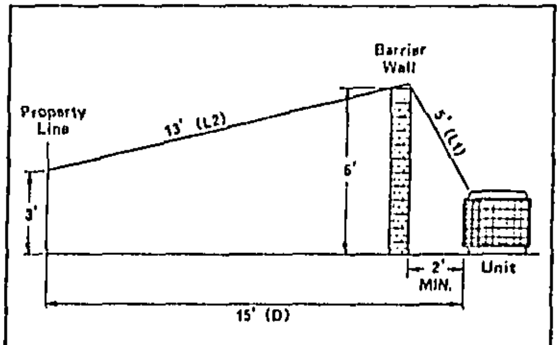
Line 3 — Add lines 1 & 2 . . . "21".

Line 4 — Calculate barrier factor from barrier sketch, using the formula:

$$X = L_1 + L_2 - D$$
$$X = 5 + 13 - 15$$
$$X = 3$$

Enter value of X in table on page 9. X(3) equals a factor of "4".

Complete lines 5 through 8.



BARRIER SKETCH

Plot SLN (17) and distance factor (15) on nomograph (Table 1, page 11). Predicted dBA is 52, a reduction of 10 dBA with the addition of a barrier wall.

Problems B & C — Complete on your own to increase your proficiency. (Answers appear in lower left hand corner.)

Problem Set 2

Problem A — Determine Sound Rating Number (SRN) from either ARI Directory or manufacturer's spec sheets. Enter result on line 1 (We'll assume 20 to be SRN).

Find Equipment Location Factor from Reference Guide (Figure 1, page 6). Factor is "1". Enter "1" on line 2 of worksheet.

Add lines 1 & 2. Enter "21" on line 3.

Determine Barrier Shield Factor — No barrier shield in this example. Enter "0" on line 4 of worksheet.

Sound Path Factor — See page 10 (Path A). The evaluation is to a *point outdoors*. Enter factor of "0" on line 5. Total lines 4 & 5. In this example it's "0".

Sound Level Number — Subtract line 6 from 3. SLN is "21". Find distance from unit to evaluation point. (From plot plan on installation sketch.) In this example it is 34 feet.

Plot SLN of "21" and distance factor of 34' on nomograph (Table 1, page 11). Result for this example is 58 dBA. Continue on your own with problems B and C (answers appear in lower left hand corner).

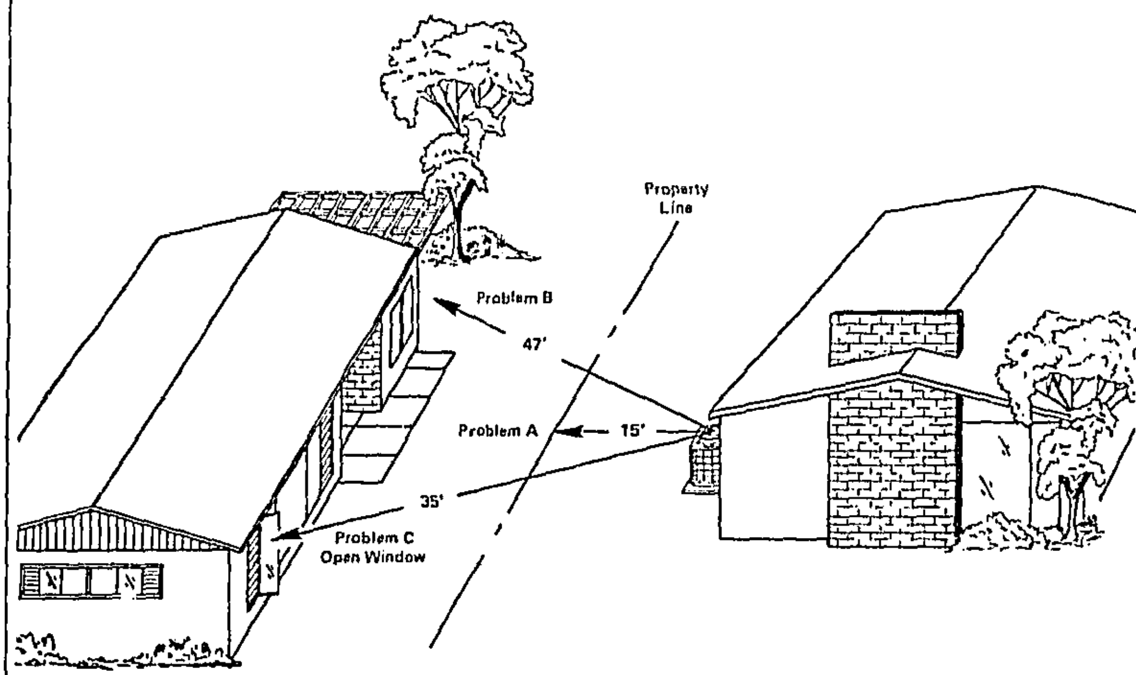
Problem Set 3

Problem A has been completed. Review and work problems B and C to increase your speed and skill.

Problem Set 4 — Multiple Units

Predicting one noise level for two or more units is done in much the same manner as in previous examples. Complete lines 1 through 9 for each *individual unit.* Line 10 — Select the two highest numbers from line 9. The two highest in this example are 53 & 48. Subtract these two values. Refer to Decibel Addition Chart, page 7. Enter value of 5 in column headed DIFFERENCE BETWEEN SOUND LEVELS (See dotted line). *Read number to be added to highest sound level.* In this example it is 1.25. Add this value to the highest number (53 + 1.25 = 54.25). With this value, subtract the next largest number (54.25 -35 = 19.25). Enter result in chart — value is greater than 10; *therefore, there is no increase in sound level* (54.25 + 0 = 54.25). The total predicted sound level for this problem is 54.25.

INSTALLATION SKETCH

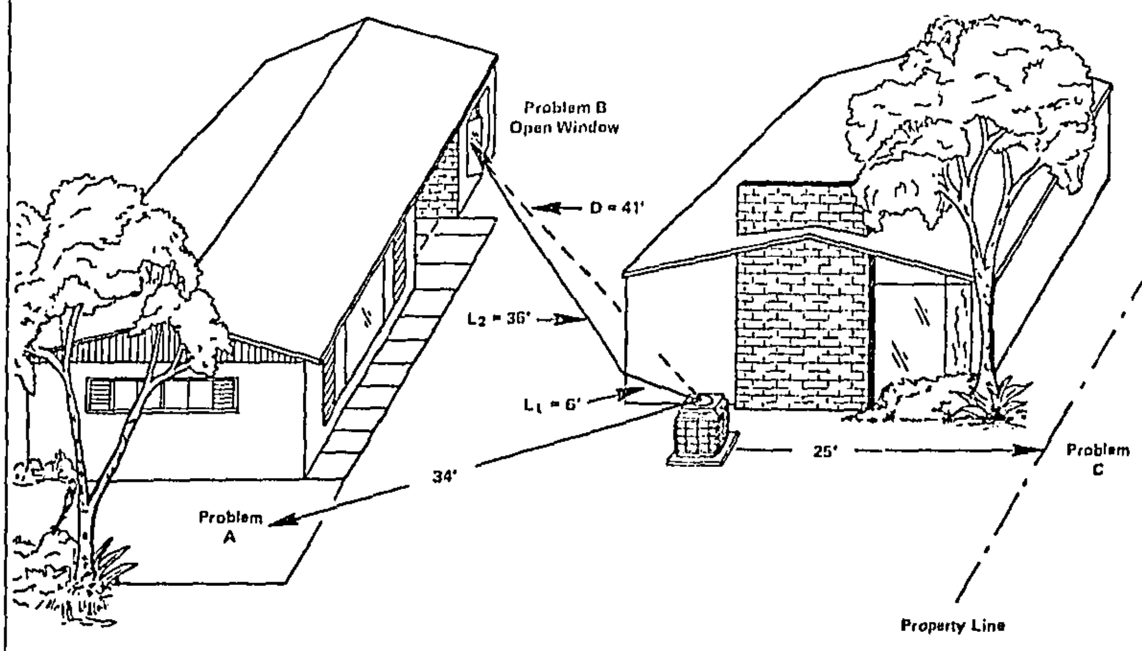


WORKSHEET – PROBLEM SET 1

LINE NO.	DESCRIPTION	EVALUATION POINTS			
		PROBLEM A		PROBLEM B	PROBLEM C
		PART 1	PART 2		
1	ENTER SOUND RATING NUMBER (From ARI Directory or Spec Sheet)	19	19	19	19
2	FIND EQUIPMENT LOCATION FACTOR (See Application Reference Guide, page 8)	1	2	1	1
3	ADD LINES 1 & 2	20	21	20	20
4	CALCULATE BARRIER SHIELDING FACTOR (See Reference Guide, page 9)	0	4*	0	0
5	FIND SOUND PATH FACTOR (See Reference Guide, page 10)	0	0	0	3
6	ADD LINES 4 & 5	0	4	0	3
7	FIND SOUND LEVEL NUMBER (Subtract Line 6 from Line 3)	20	17	20	17
8	DETERMINE DISTANCE FACTOR	15	15	47	35
9	PREDICTED dBA LEVEL (Refer to Table 1, page 11)	62	52	52	44.5

*SEE PAGE A-2 FOR THIS CALCULATION

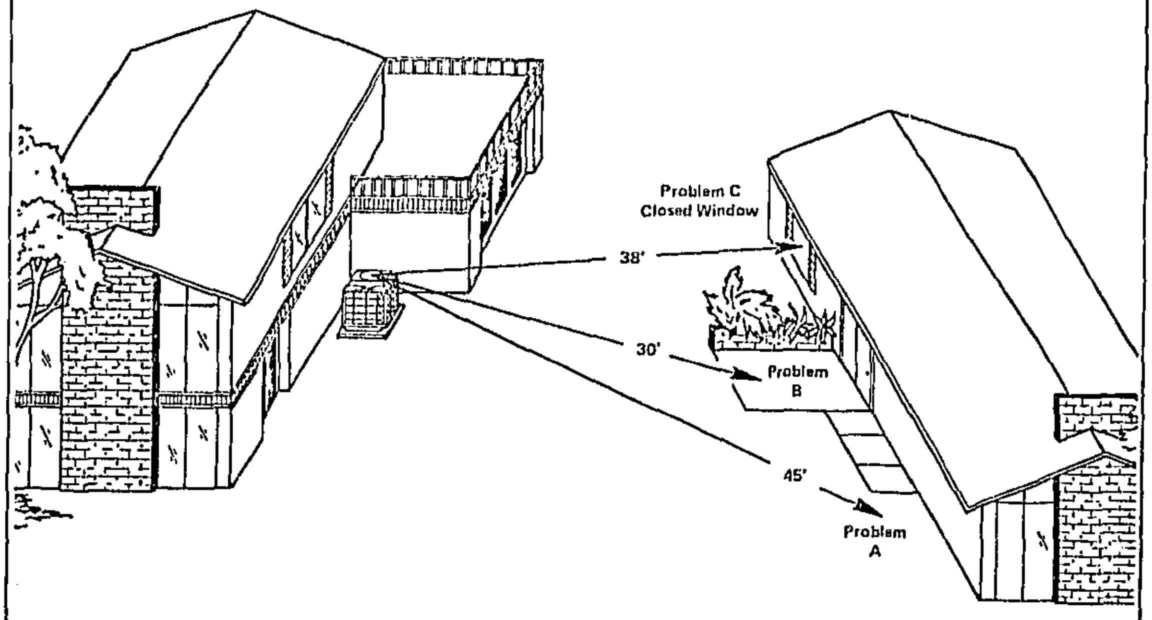
INSTALLATION SKETCH



WORKSHEET — PROBLEM SET 2

LINE NO.	DESCRIPTION	EVALUATION POINTS		
		PROBLEM A	PROBLEM B	PROBLEM C
1	ENTER SOUND RATING NUMBER (From ARI Directory or Spec Sheet)	20	20	20
2	FIND EQUIPMENT LOCATION FACTOR (See Application Reference Guide, page 8)	1	1	1
3	ADD LINES 1 & 2	21	21	21
4	CALCULATE BARRIER SHIELDING FACTOR (See Reference Guide, page 9)	0	2	0
5	FIND SOUND PATH FACTOR (See Reference Guide, page 10)	0	3	0
6	ADD LINES 4 & 5	0	5	0
7	FIND SOUND LEVEL NUMBER (Subtract Line 6 from Line 3)	21	16	21
8	DETERMINE DISTANCE FACTOR	34	41	25
9	PREDICTED dBA LEVEL (Refer to Table 1, page 11)	58	40	60.5

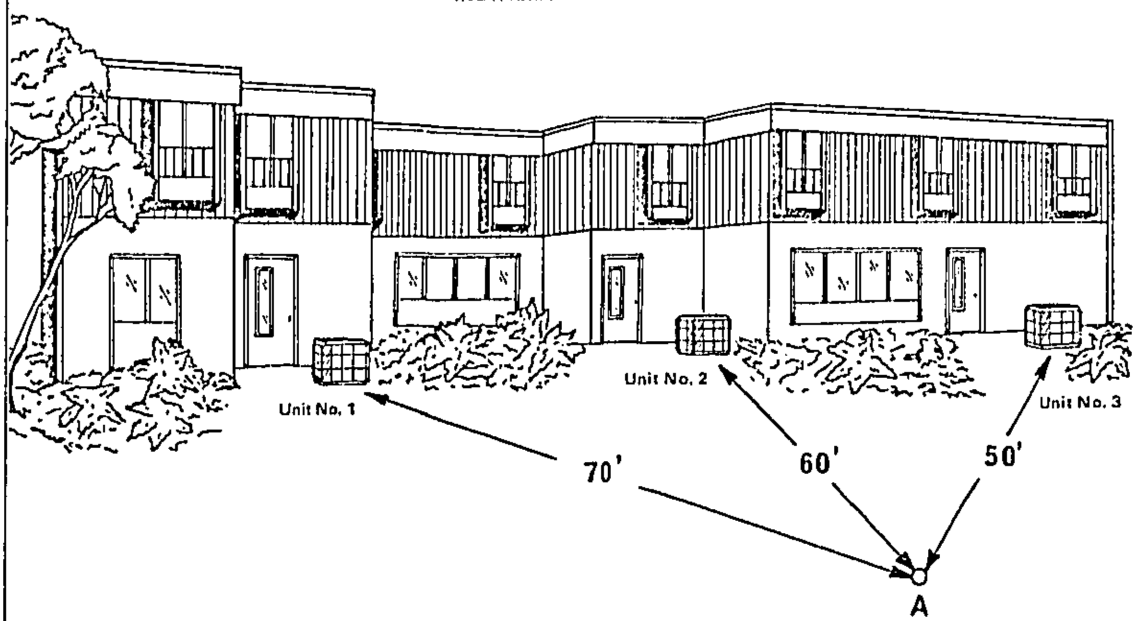
INSTALLATION SKETCH



WORKSHEET – PROBLEM SET 3

LINE NO.	DESCRIPTION	EVALUATION POINTS		
		PROBLEM A	PROBLEM B	PROBLEM C
1	ENTER SOUND RATING NUMBER (From ARI Directory or Spec Sheet)	18	18	18
2	FIND EQUIPMENT LOCATION FACTOR (See Application Reference Guide, page 8)	2	2	2
3	ADD LINES 1 & 2	20	20	20
4	CALCULATE BARRIER SHIELDING FACTOR (See Reference Guide, page 9)	0	0	0
5	FIND SOUND PATH FACTOR (See Reference Guide, page 10)	0	0	5
6	ADD LINES 4 & 5	0	0	5
7	FIND SOUND LEVEL NUMBER (Subtract Line 6 from Line 3)	20	20	15
8	DETERMINE DISTANCE FACTOR	45	30	38
9	PREDICTED dBA LEVEL (Refer to Table 1, page 11)	52	56	37

INSTALLATION SKETCH



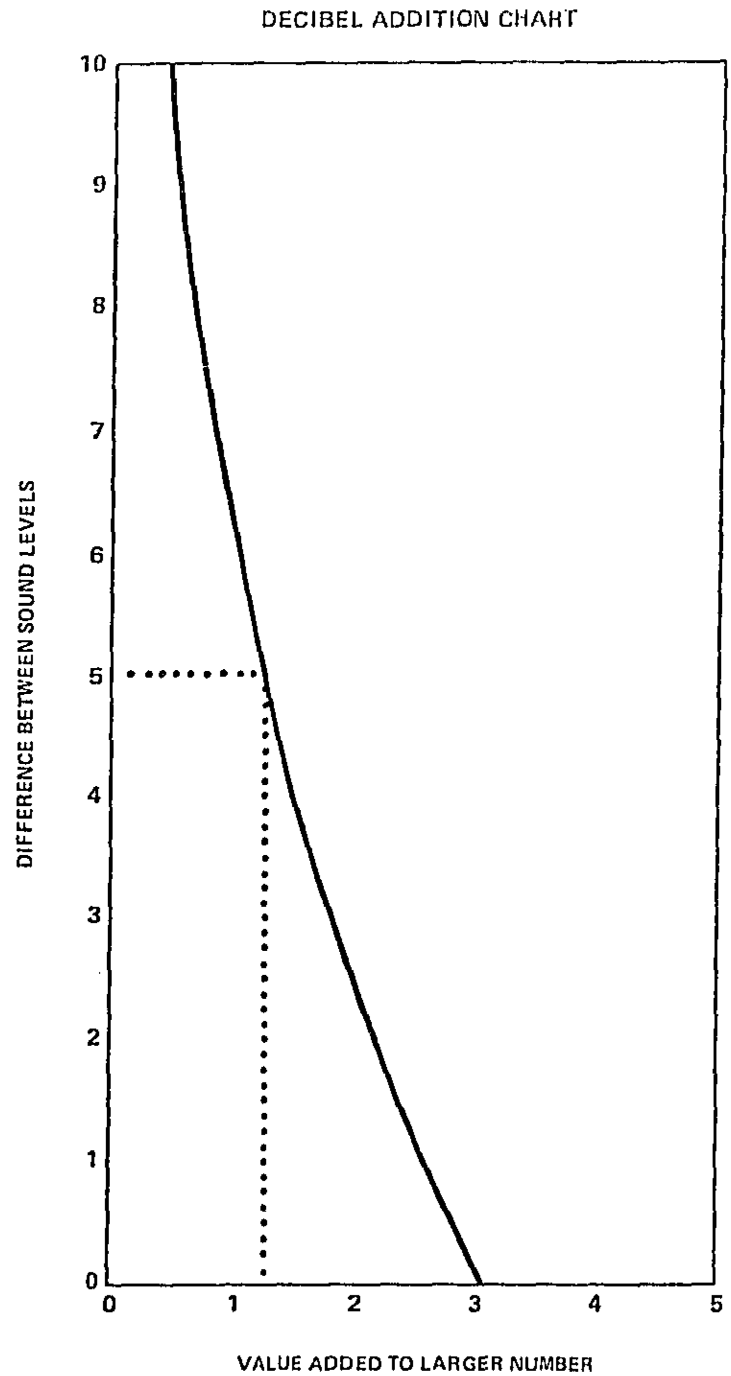
WORKSHEET — PROBLEM SET 4 (Multiple Units)

LINE NO.	DESCRIPTION	EVALUATION POINTS UNIT NO. 1	UNIT NO. 2	UNIT NO. 3
1	ENTER SOUND RATING NO. (FOR EACH UNIT)	15	19	18
2	FIND EQUIPMENT LOCATION FACTOR–PAGE 8	1	2	1
3	ADD LINES 1 & 2	16	21	19
4	CALCULATE BARRIER SHIELDING FACTOR–PAGE 9	0	0	0
5	FIND SOUND PATH FACTOR–PAGE 10	0	0	0
6	ADD LINES 4 & 5	0	0	0
7	FIND SOUND LEVEL NUMBER (Subtract Line 6 from Line 3)	16	21	19
8	DETERMINE DISTANCE FACTOR	70	60	50
9	PREDICTED dBA LEVEL (REFER TO TABLE 1 – PAGE 11)	35	53	48

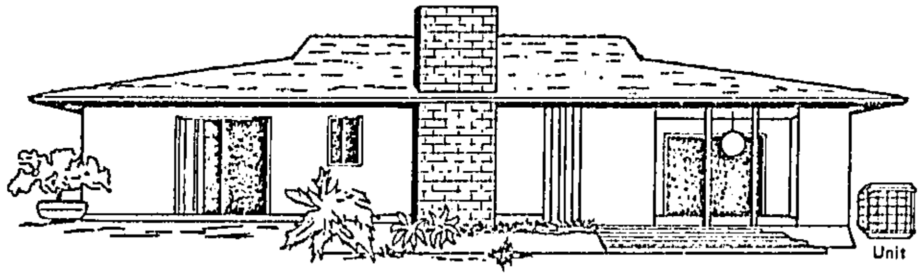
10	a.)	SELECT LARGEST VALUE FROM LINE 9	53
	b.)	SELECT NEXT LARGEST VALUE FROM LINE 9	48
	c.)	SUBTRACT 10(b.) FROM 10(a.)–ENTER DIFFERENCE	5
	d.)	ENTER VALUE FROM LINE 10(c.) IN DECIBEL ADDITION CHART ON PAGE 7. FIND VALUE TO BE ADDED TO LINE 10(a.)	1.25
	e.)	ADD LINES 10(a.) & 10(d.)	54.25

11	a.)	ENTER THIRD LARGEST VALUE FROM LINE 9	35
	b.)	SUBTRACT 11(a.) FROM 10(e.)	19.25
	c.)	ENTER VALUE FROM LINE 11(b.) IN DECIBEL ADDITION CHART ON PAGE 7. FIND VALUE TO BE ADDED TO LINE 10(e.)	0
	d.)	ADD LINES 10(e.) & 11(c.)	54.25
	e.)	PREDICTED dBA	54.25

PLEASE NOTE: The calculations used for multiple installations differ from ARI Standard 275-69.

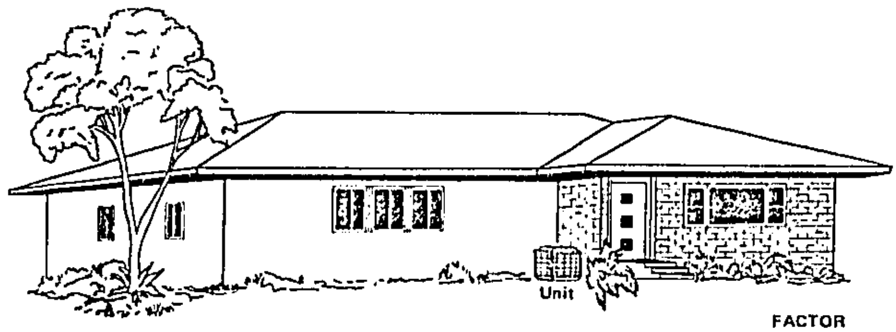

DECIBEL ADDITION CHART
DIFFERENCE BETWEEN SOUND LEVELS
0
1
2
3
4
5
6
7
8
9
10
0
1
2
3
4
5
VALUE ADDED TO LARGER NUMBER

EQUIPMENT LOCATION FACTOR – REFERENCE GUIDE



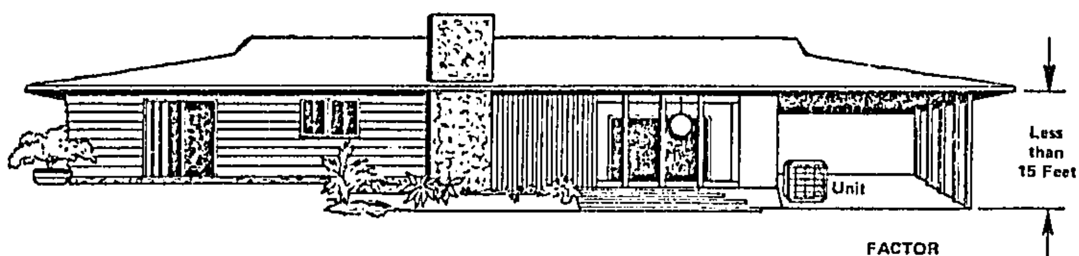
	FACTOR
a) NO REFLECTIVE SURFACE WITHIN 10 FEET	0
b) ONE REFLECTIVE SURFACE–10 FEET OR LESS	1

FIGURE 1



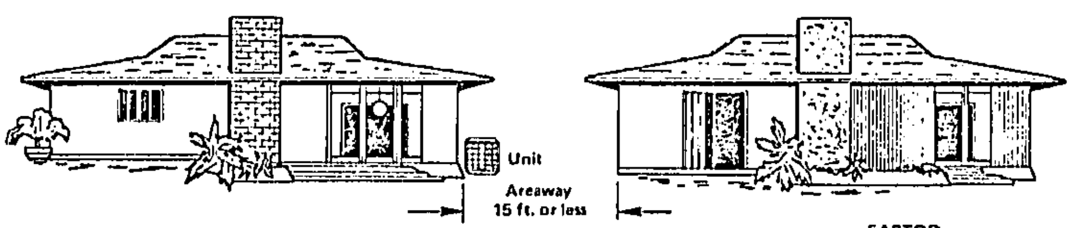
	FACTOR
TWO ADJACENT REFLECTIVE SURFACES–10 FEET OR LESS TO BOTH SURFACES	2

FIGURE 2



	FACTOR
TWO OPPOSITE REFLECTIVE SURFACES–15 FEET OR LESS	2

FIGURE 3



	FACTOR
TWO OPPOSITE REFLECTIVE SURFACES–15 FEET OR LESS	2

FIGURE 4

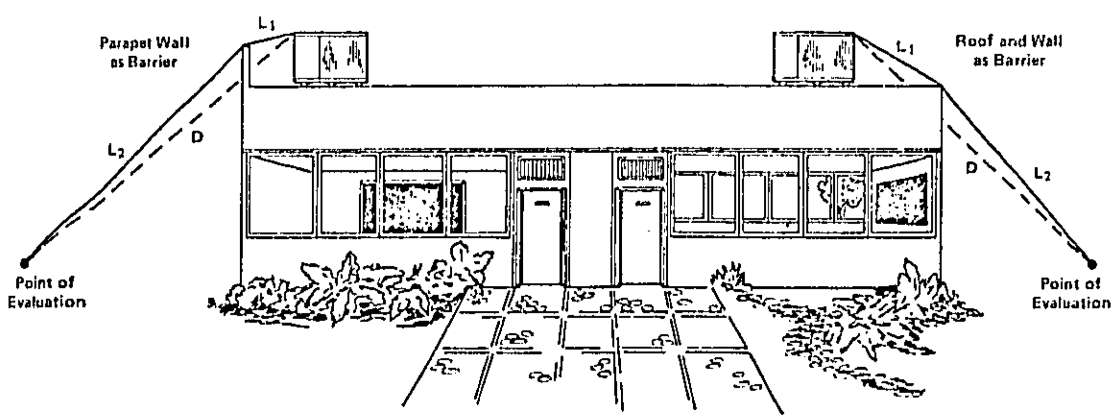
BARRIER SHIELDING FACTOR – REFERENCE GUIDE

SELECT APPROPRIATE EXAMPLE THAT MATCHES YOUR REQUIREMENT–THEN CALCULATE BARRIER FACTOR USING THE FORMULA: $X = L_1 + L_2 - D$

$L_1 + L_2$ ARE DISTANCES AROUND OR OVER BARRIER
D IS DIRECT DISTANCE FROM POINT OF EVALUATION TO UNIT

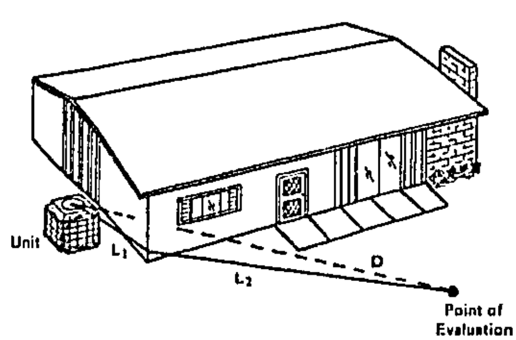
ENTER VALUE OF "X" IN TABLE BELOW – & READ FACTOR

X =	0.5	1	2	3	6	12
FACTOR	1	2	3	4	5	6



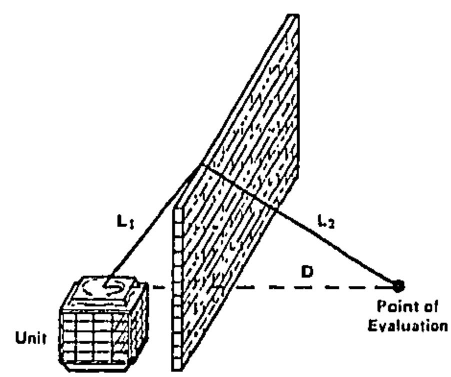
Parapet Wall or Roof and Wall as Barrier

FIGURE 5



Corner of Building as Barrier

FIGURE 6



Wall as Barrier

FIGURE 7

SOUND PATH FACTOR – REFERENCE GUIDE

SELECT APPROPRIATE "PATH" APPLICABLE TO INSTALLATION – THEN READ FACTOR FROM TABLE BELOW.

PATH	EVALUATION POINT	FACTOR
A	TO A POINT OUTDOOR	0
B	TO ROOM THROUGH OPEN WINDOW OR OPEN DOOR	3
C	TO ROOM THROUGH CLOSED SINGLE GLASS WINDOW OR DOOR	5
D	TO ROOM THROUGH CLOSED DOUBLE GLASS WINDOW OR SOLID WALL	7

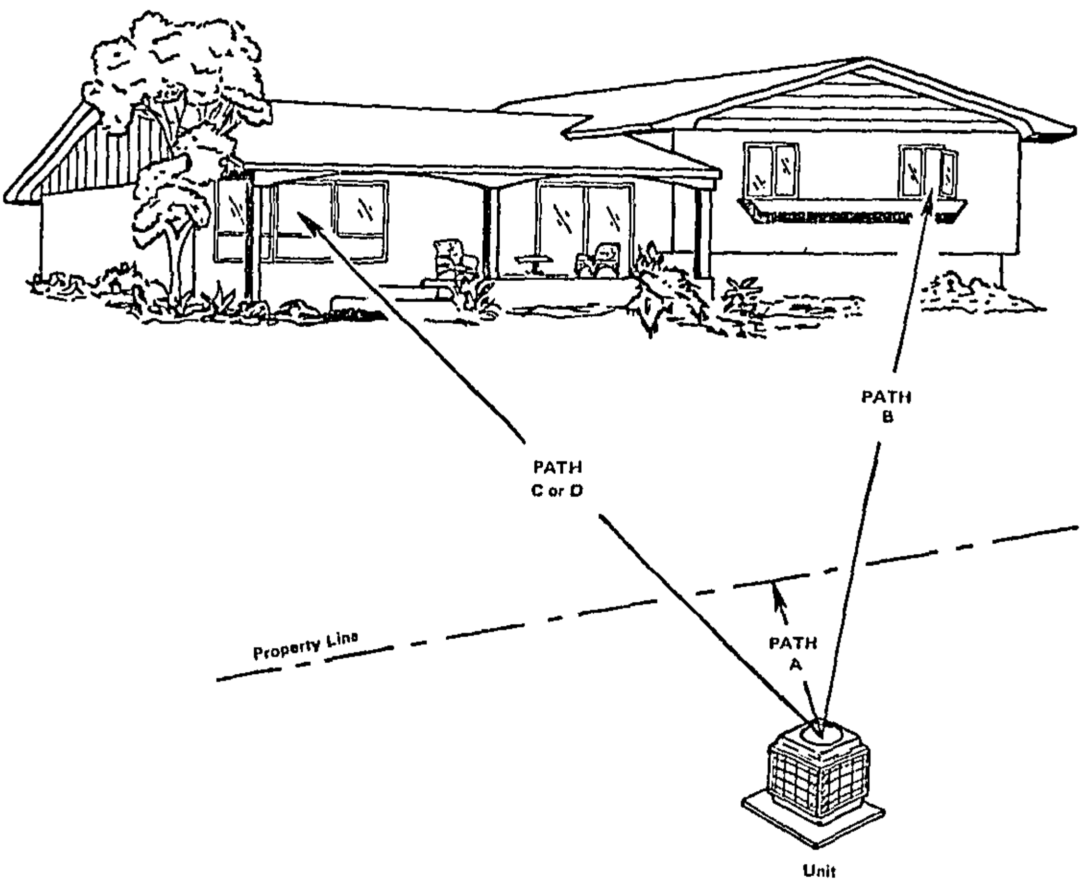


FIGURE 8

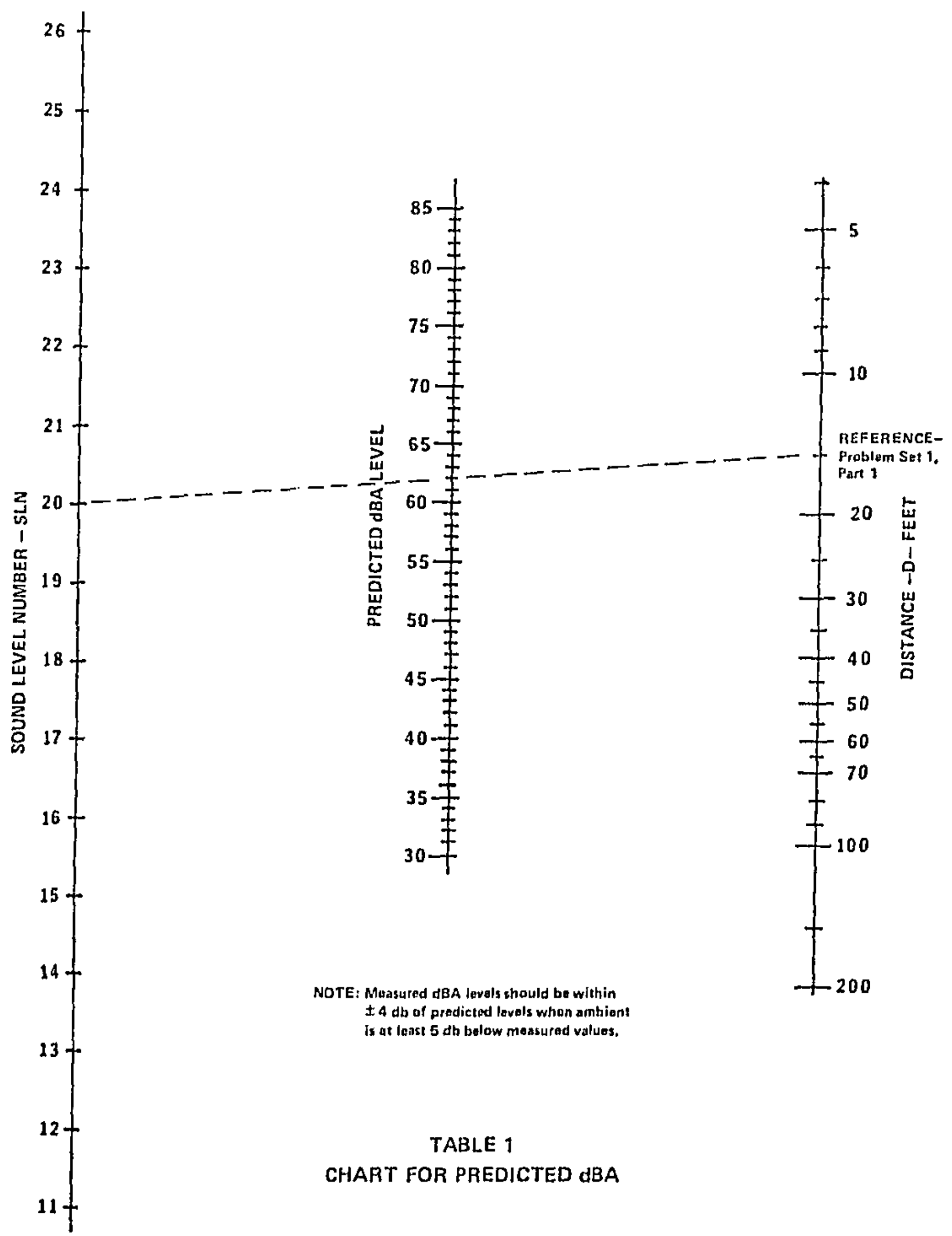


TABLE 1
CHART FOR PREDICTED dBA

APPENDIX B

SUPPLIER	BRAND OF MATERIALS
E. J. Bartells Co. 700 Powell SW Renton, WA 98055	Ferro Cousti-Products Eckel Industries United States Gypsum Johns-Manville Pittsburgh Corning ASARCO Vyon
Dayne Hansen & Associates 15238 28th Avenue S.W. Seattle, WA 98166	Soundcoat Products
Owens-Corning 6020 6th South Seattle, WA	Owens-Corning Fiberglass