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NOISE CONTROL FOR MECHANICAL EQUIPMENT

HEADQUARTERS, DEPARTMENT OF THE ARMY

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SECTION I - INTRODUCTION

1-01. PURPOSE AND SCOPE. This manual provides noise control data and criteria for building construction at Army installations in the continental United States (CONUS). It also serves as a basic reference for noise control for design and construction of Army facilities world-wide. Criteria herein apply to all new construction of Army facilities in CONUS and to major alteration of existing structures. Army facilities requiring higher standards because of special function or mission are not covered in this manual; criteria for these and further exceptions are normally contained in a design directive. Where standards given in this manual and referenced documents do not provide for all the functional and structural needs of a project, recognized construction practices and design standards will govern. This manual does not cover power plant acoustics. For noise control criteria for design and construction of power plants refer to TM 5-805-9, "Power Plant Acoustics," which is referenced frequently hereinafter as "PPA."

1-02. GENERAL. This manual presents: (a) data for estimating noise levels for operation of electrical and mechanical equipment most frequently used in buildings, and basic noise criteria for determining acceptable noise and vibration levels of that equipment in buildings; (b) characteristics of various treatments available to control noise and vibration in buildings, and criteria to achieve satisfactory noise level environments within buildings; and related information.

During the early stages of design of a building, it is usually impossible to know the exact size, type, speed or manufacturer of the mechanical equipment that may ultimately be used in the building. Yet is is essential that the architect and engineer design into the building the features necessary to the adequate control of the noise and vibration produced by the equipment. The real purpose of this manual, then, is to provide a means for estimating the noise levels of the equipment and to give technical data for determining the noise and vibration control structures of the building, even before the equipment bids are submitted and the final selection made.

1-03. EQUIPMENT INCLUDED. The types of equipment included in this manual are as follows:

Refrigeration System Equipment

- Packaged chillers with reciprocating compressors
- Packaged chillers with rotary-screw compressors
- Packaged chillers with centrifugal compressors
- Built-up refrigeration machines
- Absorption machines

Heating System Equipment

- Boilers
- Steam valves

Liquid Circulation System Equipment

- Cooling towers and evaporative condensers
- Pumps
- Piping and plumbing+

Prime Mover Equipment

- Electric motors
- Steam turbines
- Gears

Electric Equipment

- Transformers
- Switch gear+

Air Compressors

For those items marked with a plus sign (+), actual noise or vibration levels are not provided, but recommendations are given for providing a suitably quiet installation.

1-04. EQUIPMENT EXCLUDED. This manual does not include noise data or recommendations concerning:

Fans

Air distribution systems

(ducts, air valves, diffusers, etc.)

Lighting system

(dimmers, ballasts, fluorescent lamps, etc.)

Personnel or material conveyance systems

(elevators, escalators, conveyors, etc.)

External noise and vibration sources

such as vehicles, railroads, aircraft, highways, precipitation, thunder or wind-induced vibration.

In the absence of noise data and recommendations in this manual for any of the components of the air handling system, it is suggested that the latest issue of the ASHRAE Guide and Data Book be used. See Reference [2] in Section VI of the manual.

1-05. EQUIPMENT LOCATIONS. Data and recommendations are given for equipment installations on-grade and in upper-floor locations of steel and concrete buildings. Vibration isolation recommendations do not apply for this equipment located in upper floors of buildings of all-wood constructions.

1-06. APPLICABILITY OF NOISE DATA. A large quantity of noise data have been collected and studied for this manual. Noise level estimates are derived for each type of equipment, in some cases graded for power or speed variations of the noise producing machines. The noise level estimates generally are set near the upper limit of the range of noise levels measured for the several individual pieces of a particular type of equipment. Thus, it is believed that the noise level estimates will lead to noise control designs that will adequately "protect" approximately 80-95% of all equipment that might be encountered. It is uneconomical to design mechanical equipment spaces to contain the noise of all the noisiest possible equipment; this would require thicker and heavier walls and floors than requiredby most of the equipment, and such over-designs would be an expensive burden to the building.

The noise estimates and the noise control designs offered by this manual may be used with reasonable confidence for most general purposes. If the building involves some highly critical areas, in terms of low noise and vibration levels, it may be necessary to take special steps to assure that the required conditions are met. This could involve the use of special treatments and evaluations or the specification of maximum noise levels for equipment. A sample noise specification is offered in Paragraph 3-17 for such purposes. The assistance of an acoustical specialist might be engaged for these highly critical situations.

Where a qualified designer can apply more complete and rigorous analyses and noise data to a special or unusual noise problem, that is to be encouraged provided the designer can demonstrate the validity of his data and methods.

1-07. "POWER PLANT ACOUSTICS" MANUAL. Many of the methods and much of the data used in this manual are taken from TM 5-805-9 entitled "Power Plant Acoustics", [1] . The present manual is a sequel to "Power Plant Acoustics", and it is assumed that both manuals are available as support material for use on any particular building design authorized by the OCE.

Where it is anticipated that material from "Power Plant Acoustics" will be used frequently in the application of the present manual, that material is duplicated in the present manual. Where relatively little or infrequent use of the earlier material is required in the present manual, that material will be referred to in "Power Plant Acoustics" but not repeated here in any detail.

1-08. ABBREVIATIONS. In the manual, the following abbreviations are used.

BHP	boiler horsepower
CPM	cycles per minute
dB	decibel
HP	horsepower
Hz	Hertz (cycle per second), unit of frequency
KW	kilowatt
MER	mechanical equipment room
NC	noise criteria
NR	noise reduction
NRC	noise reduction coefficient
OCE	Office of the Chief of Engineers
PPA	"Power Plant Acoustics" manual
PSIL	speech interference level, "preferred" frequencies
PWL	sound power level
RPM	revolutions per minute
SIL	speech interference level, formerly-used frequency bands
SPL	sound pressure level
TL	transmission loss

1-09. REFERENCES. A list of reference material is given under Section VI. These references are identified within the text of the manual by numbers enclosed in brackets, as [].

1-10. TABLES AND FIGURES. Tables and figures designated by letters (A, B, C, etc.) accompany the descriptive material and are included within the text of the discussion. They are used to illustrate specific examples or calculations.

Tables and figures designated by numbers (1, 2, 3, etc.) are presented in Section VII in numerical order at the end of the manual. They are used for source data and are kept together for the convenience of the user when working on later design analyses.

Sample Data Forms are filled in and used within the text in Section IV to illustrate certain examples discussed in the text. Blank Data Forms (DA Forms 3452-14-R through 3452-20-R) are given in Section VII at the end of the manual. They may be duplicated for use on later specific analysis problems.

SECTION II - NOISE AND VIBRATION CRITERIA

2-01. INDOOR NOISE CRITERIA - "NC" CURVES. The family of curves in Figure 1 may be used to describe acceptable indoor noise environments for a large range of living and working conditions [3]. These curves are based on many earlier case histories of noise environments that people have found either "acceptable" or "unacceptable" for certain types of activities. Each curve represents a reasonably "comfortable" balance of low frequency to high frequency noise content for a variety of indoor situations. The curves are also related in a numerical way to "speech communication" conditions permitted by the noise.

The lower "NC" (Noise Criterion) curves describe noise levels (for the various octave frequency bands) that are quiet enough for resting and sleeping or for excellent listening conditions in an auditorium or large meeting room. The upper "NC" curves describe increasingly higher noise levels acceptable for generally noisier work spaces. For the highest "NC" curves even speech communication becomes difficult and restricted. The curves within this total range may be used to set desired noise level goals for almost all typical indoor functional areas where some acoustic need must be served. The octave band "sound pressure levels" for these "NC" curves are tabulated in Table 1.+

In Table 2, a number of typical indoor living, working and listening spaces are grouped together into "categories" and each category is

+Refer to pages 19-24 of "Power Plant Acoustics" [1] (OCE TM 5-805-9) for brief discussions of "sound pressure level", "sound power level" and "octave band frequencies".

assigned a representative range of noise criterion values. Low category numbers indicate areas in which relatively low noise levels are desired; higher category numbers indicate areas in which relatively higher noise levels are permissible. Any occupied or habitable area not specifically named in Table 2 can be added under any appropriate category number as long as the acoustic requirements of the new area are reasonably similar to those of the areas already named under that category. A 5 dB range of "NC" values is given in Table 2 for each of the first five categories. In general, the lower limit of each range should be used for the more critical spaces or the more sensitive or critical occupants of an area, while the upper limit of each range may be used for the less critical spaces or occupants of an area. An exception to this generalization may occur when it is clearly known that the background noise of an area is so quiet and the walls between adjoining rooms have such low "transmission loss" that speech sounds or other clearly identifiable sounds may intrude from one area to another and be disturbing to occupants of either area. In this type of situation, "masking noise" may have to be introduced into the rooms in order to reduce some of the intelligibility of the intruding sounds,+ and the higher range of noise criterion values may actually be useful, as long as the mechanical equipment noise itself is relatively unobtrusive and not too identifiable. When properly controlled as to spectrum shape and sound level, ventilation system noise (the gentle "hissing" of diffusers, under-window induction units, dampers or air valves) sometimes provides some of this "masking noise". In more critical cases, where spectrum and level must be held under close control, electronic noise sources may be used.

2-02. SPEECH INTERFERENCE LEVELS ("PSIL"). A reasonably steady broad-band noise with moderate to high noise levels in the frequency bands of 500 to 4000 Hz# will produce some degree of interference with speech, since most of the intelligibility of the human voice falls in this frequency range. The term "speech interference level" ("PSIL") of a noise is now defined as the arithmetic average of the sound pressure levels of the noise in the three octave bands centered at 500, 1000 and 2000 Hz. Table 3 gives the average "speech interference

+For a more detailed discussion of this effect, refer to pages 533-537 of Reference [4] or to Reference [5].

#The recently accepted U.S. and international standard unit of frequency is the "Hertz", abbreviated "Hz". Thus, Hertz has the same meaning and value as the traditional and familiar term "cycles per second" or "cps". The new unit Hz is used in the manual.

level" of a noise+ that will just barely permit reliable speech communication for a range of voice levels and distances. The data are based on tests performed out-of-doors where there are no reflecting surfaces to help reinforce the speech sounds, but the values can be used as approximations for indoor conditions as well. Also, to a first approximation (but not exactly), if a noise follows the shape of an "NC" curve, the "PSIL" value of the noise will nearly equal the "NC" curve number.

As a simple example of the use of Table 3, if the noise levels in a Mechanical Equipment Room average 62 dB in the 500, 1000 and 2000 Hz bands, barely reliable speech conversations could be carried on in that room by shouting at a 16-ft distance, by using a loud voice level at a distance of 8 ft, by using a raised voice at a distance of 4 ft or by using a normal voice level at a distance of 2 ft.

2-03. OUTDOOR NOISE CRITERIA. In the "Power Plant Acoustics" manual it is pointed out that the outdoor noise produced by a noise source is generally compared by a listener with the background noise that was present before the new noise made its appearance. A procedure for estimating the background noise level is given in the "Power Plant Acoustics" ("PPA") manual (pages 16-17, Table 7 and Figure 10); that material is not reproduced here.

There are two general types of conditions arising from mechanical equipment installations that involve outdoor noise considerations. The most important one pertains to outdoor transformer or cooling tower noise, and the second one pertains to noise escaping from mechanical equipment rooms (MERs) through ventilation openings. DA Forms 3452-12 and 3452-13 of the "PPA" manual may be used to determine if outdoor noise will be a problem to a nearby neighbor of the building. A specific example is given later in this manual.

2-04. CRITERIA FOR PROTECTION OF HEARING. The PPA manual (pages 8-12, Tables 1-4 and Figures 1-8) discusses in considerable detail the noise exposure conditions recommended for the preservation of hearing. That same material would apply to MERs having high noise levels. The

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+"SIL was originally defined in terms of the three formerly-used octave bands 600-1200, 1200-2400 and 2400-4800 Hz. With the acceptance of the new international frequency bands in the U.S., an adjustment of values has been made and the new values are being identified by the notation "PSIL" in order to designate that they are based on the now "preferred" frequencies. These values take procedence over the interim values used in "Power Plant Acoustics".

noise levels of some of the equipment that goes into an MER installation may exceed "safe" values, so it would be wise to apply the PPA DA Forms 3452-10 and 3452-11 to determine if special measures should be taken. In modern equipment layouts for most buildings, the equipment operator is given a Control Room (that may or may not be near the actual equipment) and he is not expected to spend full time in the MER itself. However, frequent visits are made to the MER for inspection and maintenance purposes, and if the noise levels are high or if the visits are frequent and prolonged, there is a good chance that ear protection should be worn near some machines.

Two general recommendations are made here: (1) it is suggested that a separate Control Room be provided for the operator (an enclosure with glass walls and snug fitting doors will probably be adequate) if the control area or console is located in the MER area; and (2) it is suggested that the responsible personnel involved in the use and operation of the building check the noise levels in the various MERs to determine if special hearing-protection routines should be applied. Actual measured noise levels would be preferable, but estimated noise levels obtained from later portions of this manual can be used in the absence of measured data. For any strict legal interpretation of the noise levels, measured values would be required, of course.

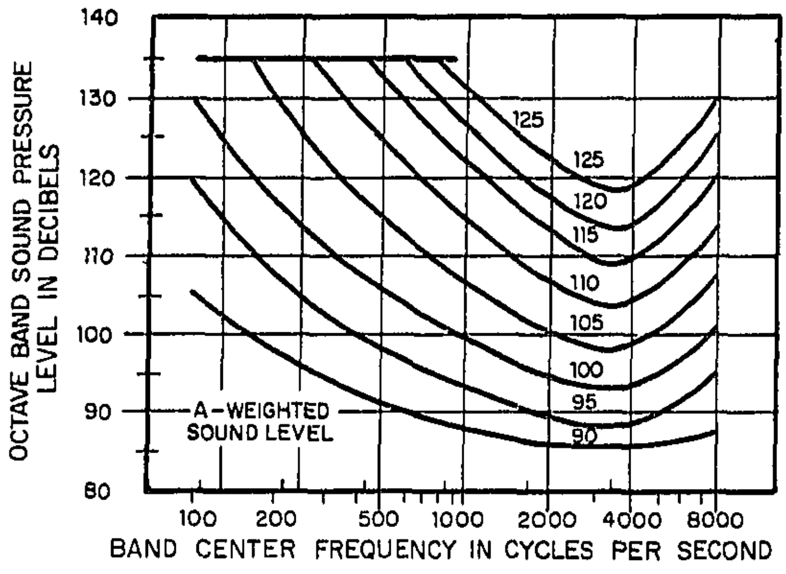
The Walsh-Healey regulation of May 20, 1969, with slight revisions in July 1969, provides federal legislation regarding permissible noise levels in certain manufacturing spaces working under government contract. It is possible that these noise limits may ultimately come into widespread use in other work spaces through other types of legislation. Thus, the noise level values are mentioned here. It would seem advisable to provide a quiet Control Room space for operating personnel who would otherwise be subjected to excessive noise exposures.

The Walsh-Healey permissible noise exposures are given at the top of the following page:

Duration per day, hours	Sound level dBA
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

These sound levels are expressed in dBA, as read from the A-scale of a sound level meter, because of the ease of taking a quick survey with a simple single-number-reading instrument.

If octave band readings for a noisy space are available, they may be plotted on the chart reproduced below to determine approximately the equivalent dBA value.



There are other details of the Walsh-Healey regulation that might be involved if this should ultimately be applied to mechanical equipment spaces, but they will not be mentioned here.

In brief summary, if a noisy space will meet the noise exposure conditions of Table 3 of PPA for 1- to 4-hour exposures it will satisfy the Walsh-Healey regulation. The Table 1 and 3 values (of PPA) should be reduced by 2 to 5 dB to meet the Walsh-Healey limits for 8-hour, 6-hour, ½-hour and ¼-hour exposures.

2-05. VIBRATION CRITERIA. An approximation of the "threshold of sensitivity" of individuals to feelable vibration is shown in Figure 2. Obviously, this may vary over a relatively wide range for different individuals and for different ways in which a person might be subjected to vibration (standing, seated, through the finger tips, etc.). The exact threshold values are not particularly important, for the purpose of this discussion, but it is considered important to realize that vibration can evidence itself in two different ways to an individual: (1) as "feelable" vibration, and (2) as "audible" sound radiated from a vibrating surface. Along the right-hand side of Figure 2, the low frequency ends of some "NC-equivalent" curves are shown. The complete "NC-equivalent" curves for this sequence are shown in Figure 3. To illustrate, using either Fig. 2 or Fig. 3, if a wall or floor of a building has a vibration acceleration level of -60 dB re 1 G at a frequency of 63 Hz, the sound level radiated by that wall or floor would be equivalent to the noise level of an NC-30 curve at 63 Hz. According to Figure 1, an NC-30 curve shows a noise level of about 57 dB (re 0.0002 microbar). In a quiet room, a 57 dB sound pressure level at 63 Hz would be faintly audible; yet Figure 2 suggests that the vibration itself would be imperceptible for -60 dB acceleration level at 63 Hz. In fact, Figure 2 reveals that the acceleration level would have to be about 20 to 30 dB higher than this value in order to be barely perceptible as feelable vibration.

The objective of this discussion is to emphasize that the sound radiated by a vibrating wall or floor may be more important in noise control than the feelable vibration of that wall or floor, especially in the frequency region above about 30 to 60 Hz. In other words, if a piece of equipment is vibration-isolated well enough to produce no audible noise radiation from a wall or floor, then it is quite probable that there will be no feelable vibration associated with that machinery (as observed in some part of the building outside the actual MER). This is especially true for equipment operating at speeds in the vicinity of 1800 RPM (or higher), which would give rise to 30 Hz (or higher) driving frequency. For slow speed machinery, the vibration isolation treatment should provide lower frequency protection.

In this manual, actual vibration levels of mechanical and electrical equipment are not given, but the vibration isolation recommendations that are given are aimed at achieving acceptable radiated noise levels (as "NC-equivalents") and essentially imperceptible "feelable" vibration levels in occupied spaces of the building.

SECTION III

NOISE DATA FOR MECHANICAL AND ELECTRICAL EQUIPMENT

Noise data have been collected and studied for fourteen different types of electrical and mechanical equipment covered by this manual . More than 250 individual items have been included in the study. The noise data have been evaluated in an attempt to correlate noise levels with some of the more obvious noise-influencing parameters, such as manufacturer, type, speed, power rating, etc. The noise data are summarized here, as a function of some of those parameters. It is believed that the noise levels given represent approximately the 80 to 95 percentile values; in other words about 80 to 95% of the equipment might be expected to have no higher noise levels than the estimates given, but possibly 5 to 20% of the equipment may have higher noise levels. The sample-size of the data would not seem to justify any finer resolution. Noise data were obtained from various sources, including some equipment manufacturers, and no known favoritism or selectivity was shown in the collection and study of the data. All acoustically reliable data were used.

3-01. SOUND PRESSURE LEVELS AT 3-FT DISTANCE. In the present collection of data, most noise levels are measured at close-in positions because (1) equipment space is usually limited; (2) most mechanical equipment spaces are somewhat similar in size (especially the height of the room); and (3) for a very major part of the data, not enough information is given about the room conditions to warrant an evaluation of sound power level. For these reasons, most of the noise data are presented in terms of sound pressure levels (SPLs) rather than sound power levels (PWLs).

In order to "standardize" all sound pressure levels to a common condition, a distance of 3 ft has been selected. This decision is based on at least three considerations: (1) because of crowded conditions in mechanical spaces most measurements are taken at close distances, (2) much of the quoted data in the literature refers to a 3-ft distance, although this is not a universally used distance, and (3) when considering the various building elements that provide noise control (walls, ceilings, floors, etc.), the floor is always a near-by element and it is not unreasonable to consider that the noise at a 3-ft distance will approximate the noise levels impinging on the floor at the base of the equipment. Thus, it appears that the 3-ft SPL values would be the highest SPLs necessary in a noise evaluation (specifically applicable to the floor) and that the levels would decrease for greater distances within the room. Also, for most applications, at 3-ft distances the noise levels are essentially in the near field of large pieces of equipment and are reasonably independent of the acoustic characteristics of the room. Thus, these close-in levels can be taken for any room and/or equipment configuration with only a small amount of uncertainty due to room acoustics. In Section IV of the manual, the SPL reduction for greater distances from the equipment will be shown.

3-02. EQUIPMENT NOISE SUMMARIES. Brief discussions of the noise of each type of measured equipment are given in the paragraphs that follow. The types of equipment included in the noise summaries are listed here:

Refrigeration System Equipment

- Packaged Chillers with reciprocating compressors
- Packaged Chillers with rotary-screw compressors
- Packaged Chillers with centrifugal compressors
- Built-up refrigeration machines
- Absorption machines

Heating System Equipment

- Boilers
- Steam Valves

Liquid Circulation System Equipment

Cooling Towers
Pumps

Prime-Mover Equipment

Electric Motors
Steam Turbines
Gears

Electric Equipment

Transformers

Air Compressors

3-03. PACKAGED CHILLERS WITH RECIPROCATING COMPRESSORS. Noise data for 24 reciprocating compressors or packaged chillers with reciprocating compressors have been collected and studied. These units range in size from 15 tons to 150 tons cooling capacity. The noise levels have been reduced to a common 3-ft distance from the front of the compressor.

In terms of noise production, it appears that the measured compressors can be divided into two groups: 15-50 tons and 51-150 tons. The two ends of the total range have been extended slightly to cover noise estimates for compressors from 10 to 175 tons. When cooling requirements exceed about 100 to 150 tons, centrifugal compressors become more economical so there are few reciprocating units rated above about 150 tons. Even in this collection of data, several of the larger units are actually made up of assemblies of two to four smaller compressors.

The suggested Design Curves based on study of all the noise data are given in Figure 4. These noise levels are also included in the upper portion of Table 4. Apparently, there is not a large enough range in speed of these machines to justify a noise adjustment for speed. Although major interest is concentrated here on the compressor component of a refrigeration machine, an electric motor is usually the drive unit for the compressor. The noise levels attributed here to the compressor will encompass the drive motor most of the time, so these values are taken to be applicable to either a reciprocating compressor alone or a motor-driven packaged chiller containing a reciprocating compressor.

3-04. PACKAGED CHILLERS WITH ROTARY-SCREW COMPRESSORS. Based on data for only three units, the octave band sound pressure levels believed to represent essentially maximum noise levels for rotary-screw compressors are listed in the middle portion of Table 4. These data apply for the size range of 100-300 tons cooling capacity, operating at or near 3600 RPM.

3-05. PACKAGED CHILLERS WITH CENTRIFUGAL COMPRESSORS. For this study, noise has been measured for 22 centrifugal type compressors. These measured compressors range in size from 140 tons to 4000 tons and represent several leading manufacturers. The noise levels may be influenced by motors, gears or steam turbines used to drive the compressors, but the measurement positions are generally selected to emphasize the compressor noise. Two design curves for noise of centrifugal compressors are given in Figure 5: one curve represents units of under 500 tons cooling capacity and one curve represents units of 500 or more tons cooling capacity+. These curves are drawn near the highest levels of the machines measured, although an occasional machine may still exceed these values. The SPLs shown by the design curves of Figure 5 are tabulated in one part of Table 4.

3-06. BUILT-UP REFRIGERATION MACHINES. The noise of packaged chillers, as presented in the preceding paragraphs, includes the noise of both the compressor and the drive unit. If a refrigeration system is to be made up of separate pieces, then the noise level estimate should include the noise of each component making up the assembly. The noise levels of the components should not be added together, but the total noise in each octave band should equal the highest noise level of each component in that octave band.

As an example, suppose a built-up refrigeration machine is to be made up of a steam turbine, a gear and a centrifugal compressor. Assume a 1000-HP steam turbine at 1800 RPM, a 1000-HP gear at 1800 RPM input speed and 3600 RPM output speed and a 1000-ton centrifugal compressor at 3600 RPM. From the other paragraphs in this section, the following 3-ft SPLs are estimated for the nine octave frequency bands from 31 Hz to 8000 Hz respectively:

for the steam turbine (from Table 14)

88	93	95	91	87	87	88	85	80

for the gear (from Table 15)

94	97	100	100	100	100	100	100	100

+A ton of cooling capacity is defined as the amount of heat removal required to produce one ton of ice per 24 hour period.

for the centrifugal compressor (from Table 4)

89 90 91 92 93 97 99 94 87

From these three rows of values, it is seen that the gear noise dominates all octave bands. The noise levels for the entire system would be estimated as the highest levels of each of the components, ie

94 97 100 100 100 100 102 100 100

3-07. ABSORPTION MACHINES. Noise data have been acquired for only two steam absorption machines for this study. More data would be sought if these were significantly noisy devices, but they are quiet enough that they are usually ignored in any noise survey of a mechanical equipment room. The machine usually includes one or two small pumps. Steam flow noise or steam valve noise may also be present.

It is believed that the noise levels given at the bottom of Table 4 will give adequate coverage of most absorption machines used in refrigeration systems for buildings.

3-08. BOILERS. Noise data have been measured or collected for at least 36 boilers, ranging in size from 50 to 2000 boiler horsepower ("BHP"). It has not been possible to correlate noise with heating capacity alone or with any other known design parameter. Noise levels at the normalized 3-ft distance may be as high for the smallest as for the largest units covered in this study. Hence, the estimated noise levels given in Table 5 are believed applicable for all boilers, although some units may exceed even these values. Note, that the quoted noise levels apply at 3-ft distance from the front of the boiler.

In the course of the study, it was learned that heating capacity of boilers may be expressed in four different ways, as follows:

(a) sq. ft of heating surface
(b) BTU/hour
(c) lb of steam/hour
(d) BHP (boiler horsepower).

To a first approximation, these terms are interrelated as follows:

10 sq. ft of heating surface = 1 BHP
33,500 BTU/hour = 1 BHP
33 lb of steam/hour = 1 BHP

For the study, all ratings were reduced to equivalent BHP. When one sees the wide variety of blower assemblies, burners and combustion chambers found on various boilers, it is no wonder that the noise output cannot be simply associated with heating capacity.

3-09. STEAM VALVES. Based on the noise level data of three groups of steam valves, mostly on high pressure steam lines, estimated noise levels are given in Table 5 for a typical thermally-insulated steam pipe and valve. Even though the noise is generated near the orifice of the valve, the pipes on either side of the valve radiate a large part of the total noise energy that is radiated. Hence, the pipe is considered, along with the valve, as a part of the noise source.

3-10. COOLING TOWERS. Sound power level data for cooling towers were given in Tables 17 and 18 of the PPA manual. Those values generally apply to the total noise output of the entire tower, regardless of tower orientation. In the present manual, (1) some relatively small adjustments are made to some of the PPA data; (2) a large amount of material is added on the directionality of various cooling tower arrangements; and (3) new data are given for close-in noise levels of towers -- near the air inlet and discharge openings.

It should be realized that the generalizations drawn here may not apply exactly to all cooling towers, but it is believed that these generalizations are one step closer toward the useful data frequently required by the architect or engineer in laying out cooling towers and cooling tower noise control treatments in any given acoustic environment. It is still desirable to try to obtain from the manufacturer actual measured noise levels for all directions of interest, but if these data are not forthcoming, it is essential to be able to construct approximately the directional pattern of the cooling tower noise.

For aid in identification, four general types of cooling towers are sketched in Figure 6:

A. the centrifugal-fan blow-through type,

B. the axial-flow blow-through type (with the fan or fans located on a side wall),

C. the induced-draft propeller-type, and

D. the "underflow" forced-draft propeller type (with the fan located under the assembly).

a. Noise Levels at a Distance. The enclosed Table 6 gives the corrected sound power levels (PWLs) for the propeller-type cooling tower. In the absence of more accurate measured or estimated data from the tower manufacturer, the Table 6 data may be used for estimating the total noise output of types B, C, and D cooling towers listed immediately above and shown in Figure 6, provided they are driven by propeller-type fans. The values in Table 6 differ from those originally given in Table 17 of the PPA manual in that 3 dB increases have been made to the power levels in the 63 and 125 Hz octave bands in recognition of the greater noise output at the blade passage frequency. Since the blade passage frequency may not be known at the time of the preliminary design, this noise increase is provided in both of the low frequency octave bands that might contain the propeller blade passage frequency. An occasional tower may have a blade passage frequency (or harmonics) in the 250 Hz octave band, but these can be ignored here since they will fall under the general protection of the estimated values.

Table 7 gives the estimated sound power levels of cooling towers driven by centrifugal-type fans, such as shown in type A of Figure 6. These data are unchanged from Figure 18 of the PPA manual.

To obtain the average outdoor sound pressure levels at any distance from an unobstructed cooling tower, a "distance term" is applied to the sound power levels+ of Tables 6 and 7. This "distance term" is taken from Tables 8 and 9, which are duplicates of Tables 46 and 47 of the PPA manual. For an example and a discussion of the calculation of SPL from PWL using the "distance term," refer to pages 67-69 of the PPA manual. Note that this calculation yields the average SPL all around the cooling tower as though there were no directionality variations of the noise.

b. Directional Corrections. It is obvious, of course, that the noise differs for different radiating surfaces of a typical tower, and it is valuable to know, at least approximately, the amount of the directional variations. Table 10 gives some approximate corrections for the directional effects of the four types of towers considered here. These corrections are to be added to the average SPLs calculated for the particular distance involved. Please note the qualifications to the use of Table 10, as given under the caption of the table. These corrections apply to the five principal directions from a cooling tower, ie, in a direction perpendicular to each of the four sides and to the top of the tower. If it is necessary to estimate the SPL at some direction other than the principal directions, one should feel free to interpolate between the values given for the principal directions.

+For a more detailed discussion of sound pressure level and sound power level, refer to pages 19-22, 36-44, and 67-69 of the Power Plant Acoustics manual or to an acoustics textbook (see References [4] and [6], for example).

c. Close-in Noise Levels. The noise data given in the preceding discussion are most useful in estimating the noise levels of cooling towers as heard at some distance away. Although the sound power level data can be used to estimate approximately the close-in noise levels, in this study considerable close-in data have been collected and are suggested for use in determining, for example, the type of wall or floor required to separate the cooling towers from quiet parts of the building. Based on the data collected and evaluated under this study, Table 11 gives the estimated close-in noise level summaries for the four types of towers. Although very little data were studied for the "underflow" tower, it would seem reasonable to expect the close-in noise levels of the axial-flow blow-through type to be comparable to those of the "underflow" type. Thus, these two types are combined in Table 11; functionally the fans perform similar operations, the only significant difference is their location relative to the tower assembly.

d. Half-speed Operation. When it is practical to do so, the cooling tower fan can be reduced to half-speed in order to reduce cooling capacity and to reduce noise. Half-speed produces approximately two-thirds cooling capacity and approximately 8-10 dB noise reduction in the octave bands that contain most of the fan-induced noise. A suggested noise reduction schedule for half-speed operation is as follows. Reduce the octave band SPLs or PWLs of full-speed cooling tower noise by the following amounts for half-speed operation, where f_B is the blade passage frequency and is calculated from the relation

$$f_B = \frac{\text{No. of fan blades x shaft RPM}}{60}$$

Octave band that contains:	Noise reduction due to half-speed:
1/8 f_B	3 dB
1/4 f_B	6 dB
1/2 f_B	9 dB
f_B	9 dB
2 f_B	9 dB
4 f_B	6 dB
8 f_B	3 dB

If the blade passage frequency is not known, assume that it falls in the 125 Hz band for propeller-type cooling towers and in the 250 Hz band for centrifugal-fan cooling towers. Waterfall noise usually dominates in the upper octave bands and it would not change significantly with reduced fan speed.

e. Limitations. The data given here represent the most complete survey to date on cooling tower noise, but it must still be expected that noise levels may vary from manufacturer to manufacturer and from model to model as specific design changes take place. Whenever possible, request the manufacturer to supply the specific noise levels for the specific needs.

In this manual, it is assumed that cooling towers will be used in outdoor locations. If they are located inside enclosed mechanical equipment rooms or within courts formed by several solid walls, the sound patterns will be distorted. In such instances, the PWL of the tower (or appropriate portions of the total PWL) can be placed in that setting, and the enclosed or partially enclosed space can be likened to a room having certain estimated amounts of reflecting and absorbing surfaces. Because of the limitless number of possible arrangements, this is not simply handled in a general way, so the problem of partially enclosed cooling towers is not treated here in detail. In the absence of a detailed analysis of cooling tower noise levels inside enclosed spaces, it is suggested that the close-in noise levels of Table 11 be used as general approximations.

f. Evaporative Condensers. Evaporative condensers are somewhat similar to cooling towers in terms of noise generation. A few evaporative condensers have been included in the cooling tower data study, but not enough units have been measured to justify a separate study of evaporative condensers alone. In the absence of noise data on specific evaporative condensers, it is suggested that noise data be used for the most nearly similar type and size cooling tower.

g. Air-cooled Condensers. For some installations, an outdoor air-cooled condenser may serve as a substitute for a cooling tower or evaporative condenser. The noise of an air-cooled condenser is made up almost entirely of fan noise and possibly air-flow noise through the condenser coil decks. Since fan noise is not included in this manual, the noise of air-cooled condensers cannot be directly related to fan noise estimates. However, in a typical cooling tower most of the low frequency noise is due to the fan system and much of the high frequency noise is due to waterfall noise. In general, the low frequency fan noise dominates. Thus, in the absence of specific data on air-cooled condensers, it would not be unreasonable to use noise data for the most nearly similar type and size cooling tower.

3-11. PUMPS. Noise data have been collected and studied for eighteen pumps ranging in size from 3 HP to approximately 800 HP and for one 2000-HP pump. All but the 2000-HP pump were used to pump hot or cold water in various typical building applications. The 2000-HP pump was used in fuel oil pipeline transmission and was located out-of-doors. This type of pump is not usually located inside occupied buildings but its noise data were included to represent a very large size pump. The various pumps covered a speed range of 450 to 3600 RPM. All pumps were loaded but not necessarily at full rated load. The name-plate horsepower of the drive motor or turbine has usually been used to rate the pump power. All noise data have been normalized to the reference distance of 3 ft in an indoor situation. Because pumps are usually located very close to their drive motors or turbines, some of the noise attributed to the pumps may actually be due to the drive unit. In most cases, however, measurement positions were selected to favor the pump noise.

From the measured noise and from some related published work by Heitner [7], the noise design curves of Figure 7 have been derived. These curves attempt to correlate noise with HP rating and speed of the pumps. The curves indicate that noise levels follow a 10 log HP relationship up to about 400 HP; above that rating it appears that the noise does not increase significantly for conventional pumps, possibly due to the greater mass and thickness of castings and frames for the larger sizes. At speeds below the range of 1600-3600 RPM, noise drops off approximately as shown in the notes in Figure 7. There may be a significant noise variation with speed for the two speed ranges of 1800 and 3600 RPM, but this did not show up in the limited number of pumps included in this study.

The pump noise levels of Figure 7 are given in tabular form in Table 12 for the various HP and speed ranges.

3-12. ELECTRIC MOTORS. The noise data of more than 90 electric motors (or groups of motors) have been accumulated and summarized. The data include tables of noise levels listed in the IEEE Publication No. 85 [8] and the Heitner paper [7], as well as noise levels collected or measured specifically for this study. The data study included large numbers of both "drip-proof" (or "splash-proof" or "weather-protected") motors and "totally-enclosed fan-cooled" (TEFC) motors, but no significant noise difference was found for these two groups. Noise levels were found to increase with HP rating and to decrease with speed approximately in accordance with the summary curves shown in Figure 8. The total range of motor power covered was 1 to 4000 HP, and the total range of motor speed was 450 to 3600 RPM. Many motors range 10 to 30 dB below the noise level curves of Figure 8, but a few motors exceed the noise curves throughout the speed and power ranges.

The noise level values of the curves of Figure 8 are summarized in Table 13.

3-13. STEAM TURBINES. Noise data for eight steam turbines have been collected under this study, covering a power range of 500 to 11,000 HP. The noise levels are found generally to increase with increasing power rating, but it has not been possible to attribute any specific noise characteristics with speed or turbine blade passage frequency (because these were not known on the units measured). Due to the small number of steam turbines tested, the noise estimation curves are drawn to envelop the noise curves of all eight turbines and to include the estimation procedure developed and suggested in the Heitner paper [7].

The noise level design curves are shown in Figure 9 and these values are given in Table 14. Although it may be surprising to find such high low-frequency noise levels (compared to the high-frequency noise levels) for high speed steam turbines, the data are considered valid and the low frequency peaks are probably associated with shaft speed of the turbines (3600-7200 RPM corresponds to 60-120 Hz).

In Figure 9 and Table 14, power ratings are listed both in HP and KW, since steam turbines frequently are used to drive generators and may then be rated in terms of electrical power. For conversion of HP to KW, or vice versa, for any of the equipment listed in this manual, use the relationship

$$HP = 1.5\ KW.$$

3-14. GEARS. Noise data have been measured or collected for nine large gears in the power handling range of 300 to 23,200 HP. Three of the largest of these were taken from data first obtained in conjunction with the gas turbine engine study for the Power Plant Acoustics Manual. Largely on the basis of those three large gears, a noise estimation procedure was given in Table 15 of the PPA Manual. It has since been found that the PPA procedure underestimates the noise of smaller gears. Hence, in Table 15 of this manual a modified noise estimate is given for gear noise. Even here, it must be conceded, nine gears do not comprise a large sample number and this estimate may not be highly accurate. There is justification for gears making more noise as both the speed and power increase, and it is generally impossible to predict the octave band in which gear tooth contacts or "ringing frequencies" of unknown gears will occur. The schedule of noise levels of Table 15 reflects these generalizations.

The gear noise data of Table 15 of this manual should be used instead of the gear noise data of Table 15 of the PPA Manual.

3-15. TRANSFORMERS. Transformers typically are covered by NEMA sound level ratings, and transformer manufacturers usually quote the NEMA ratings when asked to specify the noise output of their products. Some manufacturers, however, produce and market transformers having sound levels below the applicable NEMA ratings. These quieter transformers may be sold at somewhat higher prices.

a. NEMA Sound Level Ratings. The current NEMA Standards Publication No. TR 1-1968 [9] specifies the method for measuring and calculating the sound level rating for a transformer. In effect, the procedure consists of averaging a large number of A-scale sound level meter readings taken all around the transformer (at suitably specified positions) at distances of 1 ft from various surfaces of the transformer (or at 6-ft distances from fan-cooled radiating surfaces). The reader is referred to the various applicable NEMA publications for more detailed discussions of the procedure.

It is important to understand the significance of the NEMA "audible sound level", as it is called in the specification. Interest here is limited to 60-Hz (cycle) power. Due to the magnetostrictive action of the transformer core material, the core goes through a complete cycle of oscillation for each half-cycle of voltage change. Thus, for 60-Hz operation, maximum sound output from the core occurs at 120 Hz and its harmonics (240, 360, 480 Hz and so on). Of course, there are relatively small amounts of sound radiation at 60 Hz and its odd-numbered harmonics but these are not significant in the present discussion.

The A-scale weighting network of the sound level meter intentionally discriminates against low-frequency sound; it somewhat simulates the response of the human ear for low-level sounds at low frequency. To be specific, the A-scale network reduces the signal levels of the transformer frequencies, of interest here, by the following amounts (in accordance with ANSI standards for sound level meters):

60 Hz	-27 dB
120 Hz	-16 dB
240 Hz	-9 dB
360 Hz	-5 dB
480 Hz	-4 dB

This means, simply, that if a transformer produced at the 1-ft position a true sound pressure level of 66 dB at 120 Hz (and assuming no other components present), the A-scale reading would be 66-16 = 50 dBA. Note the designation "dBA" to indicate an A-scale reading in decibels, and note also that this value is called a "sound level" not a "sound pressure level".

Many manufacturers produce and sell transformers that are quieter than the NEMA standard for transformers. In fact, one might conjecture that the NEMA sound level standard is high enough that only the most unreasonably noisy transformers would be rejected. Even so, occasional noise problems are produced by transformers and it is the purpose of this study to protect a building against excessive noise due to a transformer that (1) possibly did not meet the NEMA standard when installed, (2) became noisier with use, (3) became noisier when under load (the NEMA rating is taken under no-load conditions), or (4) is just too noisy for the quiet surroundings. In any event, a reasonable safety factor is derived here so that increased noisiness, hopefully, will not be a future serious problem.

b. Indoor SPL of Transformers. Based on data and experience with a few noisy transformers, an estimating procedure has been derived which, it is believed, will provide a maximum reasonable sound pressure level in a transformer room based on the NEMA sound level rating for that transformer. Thus, it is necessary for the electrical engineer on the job to determine the electrical power handling requirements of the planned transformer and to estimate or obtain from a manufacturer the probable NEMA sound level rating for that transformer. The NEMA rating number (in dBA) should then be added algebraically to the values listed in the right hand column of Table 16 to obtain the estimated maximum SPLs near the transformer for the various octave frequency bands.

In this development, assumptions have been made regarding "harmonic content" of the transformer noise and the possibility of standing waves in the transformer room. For most transformers and transformer rooms, the SPLs will not be as high as the estimated values. Many transformers are quieter than the NEMA standard, many transformers do not produce unusually high 240, 360 and 480 Hz noise components, and for many installations there will be no strong standing wave build-up, so this procedure will appear to yield high sound pressure levels when tested against many existing situations. However, this procedure is designed to protect a room against the marginally "noisy" transformer in which each of these effects may be somewhat pronounced.

There are a few points to keep in mind in the application of this procedure.

1. Where a manufacturer is willing to guarantee that his product will produce a lower sound level rating than the otherwise-applicable NEMA rating, the manufacturer's sound level value (the average dBA reading taken at 1 ft distance in accordance with the NEMA method) may be used when entering Table 16 for obtaining the octave band SPLs.

2. The purchase specification should state that the sound level of the purchased transformer shall not exceed the applicable NEMA sound level rating, and that the transformer shall be removed if it does not comply.

3. Although the procedure developed here is based on transformer noise rather than cooling fan noise, it is believed that the noise estimate will protect against a reasonable amount of fan noise for any large forced-air cooled transformer.

c. Outdoor SPL of Transformers. Transformers are frequently located out-of-doors where they may be audible to the neighbors, especially if their radiated sound includes the harmonics 240, 360 and 480 Hz. An approximation of the outdoor SPL at any given distance may be determined by the following steps, which apply only to transformers and not to any other equipment considered in this manual:

(1) From the NEMA sound rating for the transformer, determine the indoor SPL at 3-ft distance with the use of Table 16

(2) Subtract from the 3-ft indoor SPL the outdoor distance term from Table 8 or 9 for the distance of interest. The resulting SPL values will approximate the SPLs of a "noisy" transformer at that outdoor distance.

The above simple approximation applies only because the indoor SPL estimate has already been increased due to the possibility of standing wave build-up inside a closed transformer room. The assumed increase for standing waves approximately offsets the conversion terms encountered in going stepwise from an indoor SPL to PWL and then to an outdoor SPL. This simplification would not apply for any other equipment, because standing waves have not been assumed for any other indoor equipment.

d. Example. Suppose that a particular transformer has a NEMA sound rating of 70 dBA. Suppose it is desired to know the maximum indoor SPL at 3-ft distance for that unit if it is to be located inside a transformer room, and to know approximately the outdoor SPL at 300-ft distance if it is to be located outside the building.

According to Table 16, the maximum SPL at 3-ft distance indoors would be

70	75	80	87	84	79	74	69	64	dB

for the octave bands 31-8000 Hz. The SPL at any other distance inside the room can be determined with the use of Figures 11 and 12 or Table 20; this material is explained later in the manual.

At 300-ft distance outdoors, the distance term is found from Table 9 to be

48	48	48	48	48	48	49	50	53	dB

for the octave bands 31-8000 Hz. When the second line of numbers is subtracted from the first line of numbers above, the resulting values are

22	27	32	39	36	31	25	19	11	dB

These are approximately the outdoor SPL estimates at the 300-ft distance, for the nine octave frequency bands.

It is reminded that this entire discussion of transformer noise assumes a "noisy" transformer, that is, one with a moderately high noise content at 240, 360 or 480 Hz. Not all transformers have high harmonic content, and not all transformers with a NEMA rating of 70 dBA will produce the above SPLs indoors or outdoors. If these estimated noise levels are likely to cause later problems at an installation, it is advised that the transformer manufacturer be requested to submit actual SPL values obtained from some similar installation.

The simple estimation procedure given above may not be appropriate for large transformers found at power generating stations or at sub-stations located along power transmission lines. For those types of transformers, which sometimes are faintly audible in quiet rural areas for distances of over one mile, special analysis and noise control are sometimes required.

3-16. AIR COMPRESSORS. Two types of air compressors are frequently found in buildings: one is a relatively small compressor (usually under 5 HP) used to provide a high pressure air supply for operating the controls of the ventilation system, and the other is a medium size compressor (possibly up to 100 HP) used to provide "shop air" to maintenance shops, machine shops or some laboratory spaces, or to provide ventilation system control pressure for large buildings. Larger compressors are used for special industrial processes or special facilities, but these are not considered within the scope of this study.

The noise levels of four small and five medium-size air compressors have been measured or collected for this manual. Seven of these have been reciprocating compressors covering the power range of 1 - 75 HP, and two have been centrifugal compressors at 10 and 20 HP. From the noise data, it has been possible to arrive at design curves that will encompass both reciprocating and centrifugal compressors in the range of 1 - 100 HP. These are shown in Figure 10, and the noise level values are given in Table 17.

3-17. SPECIFICATIONS. As stated earlier, the noise level estimates given in this manual will probably exceed the actual noise levels of approximately 80 - 95% of all those types of machinery that will be encountered in typical building use. In many cases, actual noise levels may fall 3 to 6 dB below the estimates, and for some types of equipment some noise levels may fall as much as 10 to 20 dB below the estimates. Thus, there appears to be no shortage of available equipment that will fall at or below the estimated noise levels given in the manual, and it would not appear discriminatory or unreasonable to specify that any purchased equipment for a particular building be required not to exceed the estimated values given here for that equipment. This is especially true if the actual acoustic design of a wall or floor or room treatment is dependent upon one or two particularly noisy pieces of equipment. Such a noise specification would not seem necessary for relatively quiet equipment that does not dictate noise control design for the MER or the building.

If a noise level specification is required to be met for a particular piece of equipment, and this becomes a "hardship" on the manufacturer or the owner in terms of cost or availability, the noise specification could be waived, depending on the response of all the bidders. If some bidders agree to meet the specification while others do not, this could be a valid basis for selecting the quieter equipment. If no bidders can meet the specification, the specification can be waived but it may be necessary to reevaluate the noise control requirements of the MER, if this particular equipment is so noisy that it is responsible for the noise design in the first place. Of course, it is the primary purpose of this manual to prevent just such situations as this, as too many waivers would negate the value of the noise evaluation as a part of the design phase of the building. If the equipment measured for this study represents a fair sampling, it is likely that most of the equipment would meet a noise specification.

The sample noise level specification given below offers a general set of procedures and suggestions for carrying out noise level measurements on any desired piece of equipment. This is not offered as a "standard" for noise measurements, however. Any acceptable and applicable measurement and specification procedure recommended by an appropriate standards group (such as ANSI or ISO) may be used as a basis for setting up an equipment noise specification. See References [10] .

SAMPLE NOISE LEVEL SPECIFICATION

1. The maximum sound pressure levels measured at a distance of 3 ft from the (equipment in question) shall not exceed the following decibel values in the nine "preferred" octave frequency bands

OCTAVE BAND (Hz)	SOUND PRESSURE LEVEL (dB re 0.0002 microbar)	
31	________	(Insert
63	________	desired
125	________	noise levels
250	________	in blanks,
500	________	using estimated
1000	________	noise levels
2000	________	from manual,
4000	________	if these
8000	________	are desired.)

2. At least four sets of noise level readings shall be submitted with the bid, where each set is taken at a 3-ft distance from each of the four

principal orthogonal surfaces of the equipment. Each octave band reading of each set of readings shall be no greater than the specified value of Item 1 above.

3. During the tests, the equipment shall be in normal operation at not less than 50% full rated load (or at a specified mutually acceptable load condition). The tests shall be carried out by the equipment manufacturer or by an approved testing agency, having proven capability in noise measurements and using approved measurement equipment and acceptable measurement procedures. Whenever possible, approved "standards" of measurements should apply.

4. In lieu of the tests under Item 3 above, final testing for conformance with the Item 1 noise levels may be made following complete installation of the equipment in the customer's building, provided the equipment manufacturer will remove and replace the equipment at his own expense if it fails to meet the noise tests. To be acceptable, the replacement equipment must meet the noise tests. For the on-site tests, the equipment shall be in normal operation at not less than 50% full rated load (or at a specified mutually acceptable load condition), and the tests shall be in accordance with the procedures given in Item 3 above.

5. For all noise tests, the ambient noise level of the test area shall be at least 10 dB below the specified levels of Item 1 above, and the octave band sound measurement equipment shall meet the applicable ANSI standards for that type of equipment.

3-18. MULTIPLE NOISE SOURCES (DECIBEL ADDITION). Since a mechanical equipment room generally contains several pieces of equipment, it will be necessary frequently to add together the noise levels at a particular location in the room due to a number of sources. When noise levels are combined "by decibel addition", four simple steps are involved:

1. When adding any two decibel levels together -

When two decibel values differ by:	Add the following amount to the higher value:
0 or 1 dB	3 dB
2 or 3 dB	2 dB
4 to 8 dB	1 dB
9 dB or more	0 dB

2. If there are several levels of the same value, they may be added as follows:

No. of equal levels	Add
2	3 dB
3	5 dB
4	6 dB
6-7	8 dB
8	9 dB
9-10	10 dB
N	10 log N dB

3. The individual components can be added in any order. The total, using this simplified procedure, will give an answer which is correct to within 1 dB.

4. When combining the octave band contributions of different sources, add only noise levels from the same octave frequency band.

These four steps are repeated in Table 18 at the end of the manual, for the convenience of the user. An example of "decibel addition" will be given later in the manual.

SECTION IV

CONTROL OF AIRBORNE NOISE OF MECHANICAL AND ELECTRICAL EQUIPMENT

In practical terms, the objective of this manual is to provide assistance in the acoustic design of the Mechanical Equipment Room (MER), so that the airborne noise that escapes from that room is not disturbing to occupants of the rooms above, below and beside the MER nor to neighbors outside the building. In effect, it is necessary to know (1) the noise levels made by the equipment inside the MER, (2) the desired noise levels for the areas immediately adjoining the MER, and (3) the noise reduction that can be provided between the noisy MER and the quieter adjoining rooms by such structures as walls, floors, ceilings, doors, corridors and other acoustic treatments.

Section II of this manual discusses briefly the noise levels that are considered desirable or acceptable for various kinds of room uses. Section III gives basic noise levels at a standardized 3-ft distance for much of the equipment found in a typical MER. Section IV now gives (1) information on the variation of noise levels inside the MER for distances greater than 3 ft from the equipment, and (2) information on the "noise reduction" provided by walls, floors, acoustic treatments, etc., in limiting the escape of noise outside the MER. A somewhat more elaborate discussion of some of this material is given in the Power Plant Acoustics (PPA) Manual, or can be found in acoustic textbooks.

4-01. SOUND DISTRIBUTION IN A ROOM. a. SPL Variation with Distance. It is generally true that the sound pressure level (SPL) drops off as one moves away from the sound source. In an outdoor "free-field" situation (no reflecting surfaces except the ground), the SPL drops off at the rate of 6 dB for each doubling of distance from the acoustic center of the source (there are qualifications to this generalization that can be ignored for the present). In an indoor situation, however, all the enclosing surfaces of a room confine the sound waves so that they cannot continue spreading out indefinitely and become dissipated with distance. Instead, as the sound waves bounce around within the room, although a certain amount of energy is absorbed at each reflection, in general, there is a build-up of sound level because the sound energy is "trapped" inside the room and cannot escape (somewhat figuratively speaking). In a highly reverberant room, with walls that are hard, rigid and completely impervious, very little sound energy is absorbed at each reflection so the sound bounces around a long time before it ultimately is absorbed. In this type of room, the room becomes almost "saturated" with sound; and as one moves away from the sound source, the sound level drops off very slowly with distance (possibly only 1/2 to 1 dB per doubling of distance for some relatively small, but very reverberant rooms). In a highly absorptive room, however, a considerable amount of energy is absorbed at each reflection as the sound waves bounce around the room. There is less build-up of sound within the room; and as one moves away from the sound source, the sound level drops off more rapidly (possibly 2 to 4 dB per doubling of distance). Note that the walls would have to be 100% absorptive in order to have no reflected sound at all. This would then simulate the outdoor free-field condition, and the sound level drop-off with distance would become the theoretical maximum of 6 dB per doubling of distance.

Thus, in a qualitative sense, it is seen that the reduction of sound pressure level indoors, as one moves across the room away from the sound source, is dependent on the degree of absorption and, of course, on the distance that one moves. The amount of absorption also involves surface areas of the room. All of this is expressed quantitatively by the curves of Figure 11. As an example of the use of Figure 11, suppose a room has an amount of sound absorption that produces a "Room Constant, R" value of 1000 sq ft.. At a distance of 2 1/2 ft from the acoustic center of a non-directional sound source, the "RELATIVE SPL", as read off the left hand side of the graph for the R=1000 curve, is -7 1/2 dB. At a 5-ft distance, the REL SPL becomes -11 dB, indicating a reduction of 3 1/2 dB as one doubles the distance in going from 2 1/2 to 5-ft distance. Continuing, at a 10-ft distance, the REL SPL becomes -13 dB, indicating a reduction of 2 dB as one doubles the distance from 5 ft to 10 ft. Then, at a 20-ft distance, the REL SPL becomes -14 dB, indicating a reduction of only 1 dB as one doubles the distance from 10 ft to 20 ft. The other curves for other values of Room Constant (related to room absorption) give other variations of SPL with distance away from the source. Only if a room has an infinite Room Constant (perfect sound absorption at all the side wall and ceiling surfaces), would the sound pressure level drop off indefinitely at the outdoor rate of 6 dB per doubling of distance.

Figure 11 offers a means of estimating the amount of noise level reduction for a piece of mechanical equipment in a room as one moves from the 3-ft distance (used as the reference distance in all the data summaries of Section III) to any other distance in the room, provided one knows the Room Constant of that room. The next step is to calculate or estimate the value of the Room Constant.

b. Room Constant. A suitable acoustics textbook (such as Reference [4] or [6]) will give details of a fairly accurate calculation of the Room Constant for any specific room, knowing (1) all the room dimensions, (2) the wall, floor and ceiling materials, (3) the amount and type of acoustic absorption materials, and (4) the sound absorption coefficients of the acoustic materials at various specified frequencies. For the purpose of this manual, however, such a high degree of accuracy is not considered necessary, so a simplified estimating procedure is suggested. This procedure is also used and described in the PPA Manual. It must be recognized that this simplification yields a less accurate estimate than does the more detailed textbook procedure, but it is nevertheless considered acceptable for use in this manual. Refer to pages 36-44 in the PPA Manual for a somewhat more detailed explanation. The basic steps of the simplified procedure are listed as follows:

1. Determine the total interior surface area of the room.

2. Determine the total area of acoustic absorption material to be applied to the walls and/or ceiling of the room.

3. From steps 1 and 2, determine the percentage of total room surface covered with absorption material.

4. From Part A of Table 19 determine the "room label" associated with the percentage figure found in step 3 above.

5. Calculate the volume of the room, in cu. ft.

6. From Figure 12, using the volume of step 5 and the "room label" of step 4, determine the approximate Room Constant (R in sq ft) for the room. This value applies for octave band frequencies of 500-8000 Hz.

7. Determine the corrected values of R for 31-125 Hz as given in Part B of Table 19. The values differ depending on the type of acoustic treatment used. See the footnotes of Table 19 regarding "NRC" values normally associated with 1 in. and 2 in. thick acoustic absorption materials.

c. Example. Assume a room 40 ft long, 30 ft wide and 15 ft high. The total interior surface area is 4500 sq ft and the volume of the room is 18,000 cu. ft. Suppose 2 in. thick acoustic panels having an NRC of 0.80 are used over the full ceiling area and in a 5-ft wide band around all four walls. The total area of acoustic treatment is 1900 sq ft, giving

42% area coverage. In Table 19, 42% is seen to fall about midway between a "Medium-Dead Room" and a "Dead Room". In Figure 12, for a room volume of 18,000 cu. ft and a room label between "Medium-Dead" and "Dead", the value of R is found to be approximately 2000 sq ft. This value would apply for 500-8000 Hz. At lower frequencies, the value of the corrected R would be (from Part B of Table 19):

0.2 R or 400 sq ft at 31 Hz

0.3 R or 600 sq ft at 63 Hz

0.5 R or 1000 sq ft at 125 Hz

0.8 R or 1600 sq ft at 250 Hz.

Continuing this example, suppose it is desired to find the SPL reduction in this room while going from 3-ft to 20-ft distance from the noise source. In Figure 11, find the difference in REL SPL between 3 ft and 20 ft for R values of:

400, 600, 1000, 1600 and 2000 sq ft.

These are as follows, in order:

3 4 5 6 and 7 dB.

Thus, the 3-ft SPLs for the particular piece of equipment would be reduced by these amounts to obtain the 20-ft SPLs for the frequency bands, in order:

31, 63, 125, 250 and 500-8000 Hz.

d. Simplified Table for Distance and Room Constant. The preceding paragraphs show the normal procedure for estimating the effect of SPL drop-off with distance as one moves away from a noise source in a room having an estimated Room Constant. The material of Figure 11 is placed in a simpler form in Table 20 for the specific condition of estimating the SPL drop-off from the normalized 3-ft distance given for most equipment in this manual. Obviously, not all distances nor all Room Constants can be included to cover a wide range of usage. Various intermediate values of D and R can be determined by interpolation within Table 20 or by using Figure 11.

To illustrate the use of Table 20, recall the example given immediately above. In that example a room was found to have the following Room Constant values

400, 600, 1000, 1600 and 2000 sq ft

for the octave bands

31, 63, 125, 250 and 500-8000 Hz.

It was desired to find the SPL reduction in going from 3 ft out to 20 ft. Using Figure 11 it was necessary to determine the REL SPL at 3 ft and the REL SPL at 20 ft, then subtract one value from the other to obtain the SPL reduction at the greater distance. In Table 20 this is simplified merely to reading the SPL reduction for the particular values of R and D involved. Again, note that this table applies only when the "starting distance" is the normalized 3-ft distance. From Table 20 for a distance of 20 ft and for the Room Constants listed, the SPL reduction is found to be

3 4 5 6 and 7 dB, respectively.

These values, of course, agree with those given above as obtained by the longer procedure of reading and subtracting two values each from Figure 11.

It is cautioned that Table 20 must not be used to estimate an SPL value when the PWL of the noise source is given. Figure 11 still must be used when converting from a PWL value to an SPL at some specified distance.

e. SPL in a Room when PWL is Known. The above uses of Table 19 and Figures 11 and 12 assume that a 3-ft SPL is known for a given machine and it is desired to find the SPL of that machine at any distance (greater than 3 ft) within any room whose dimensions and acoustic absorption are known or can be estimated. That procedure was illustrated in the paragraphs above.

In the event that the sound power level (PWL) of some piece of equipment is known (rather than the 3-ft SPL), the same procedure may be used, with an exception. In Figure 11, the ordinate of the graph, "Relative Sound Pressure Level" (abbreviated to "REL SPL") is actually related to SPL and PWL by the equation

$$\text{SPL} = \text{PWL} + \text{REL SPL}$$

for any particular Distance D and Room Constant R. In this equation, SPL is given in the standard unit "dB re 0.0002 microbar", PWL is given in the standard unit "dB re 10^{-12} watt", and REL SPL is quoted in decibels and is the conversion term that relates SPL to PWL. Sound power levels

(PWLs) were used almost exclusively in the PPA manual, whereas SPLs are used mostly in the present manual, although PWL data are offered here for outdoor cooling tower noise evaluations. In the above equation, the REL SPL is read directly off the curve of Figure 11 for a particular D and R value. Then, since the PWL is given, the SPL can be calculated.

f. Example. Suppose a hermetic centrifugal compressor is to be installed in the acoustically treated room described above in paragraph 4-01.c, and suppose it is desired to find the SPL at a distance of 20 ft from the compressor. For this example, suppose that the compressor manufacturer submits PWL data for this unit. The PWL values are listed in Column 2 of the accompanying table. From paragraph 4-01.c, it was learned that the Room Constant had the values 400, 600, 1000, 1600 and 2000 sq ft at the various frequencies. From Figure 11, REL SPL values can be determined for the particular Room Constant values at a 20-ft distance. These values are shown in Column 3 of the table below. Finally, since

$$SPL = PWL + REL\ SPL,$$

the SPLs can be calculated. These are listed in Column 4.

Col. 1 Octave Band (Hz)	Col. 2 PWL (dB re 10^{-12} W)	Col. 3 REL SPL (dB)	Col. 4 SPL at 20 ft (dB re 0.0002 microbar)
31	95	-10	85
63	93	-12	81
125	94	-14	80
250	95	-16	79
500	99	-17	82
1000	102	-17	85
2000	108	-17	91
4000	105	-17	88
8000	94	-17	77

g. Qualifications. There are two additional points that should be kept in mind in using the data of Figure 11. These are both suggested by the caption under the abscissa of the graph: "Equivalent distance from acoustic center of a non-directional source". Strictly speaking, very few noise sources in real life are completely non-directional sources, but in this manual and in many conventional noise problems the assumption is made that the source is non-directional, that is, that it radiates sound equally in all directions. If the true directional characteristics are known, they may be used, but for the purpose of the manual this is not required. The second point regards the "distance from the acoustic center." The acoustic center, as the term implies, is the location that would be occupied by a "point source" of equal sound power output. The acoustic center of a noise source may be at a near-by surface of the unit being measured, or it may be located somewhere near the geometric center inside the unit. For a strictly correct use of Figure 11, the distance should be referred to the acoustic center, but in practice the location of the center is not always known, or it might be assumed to be at different locations by different individuals. Hence, for practical purposes, it is suggested that distances be related to the nearest external surface that is generally considered to be the noisiest part of the unit. This will yield consistent and reasonably accurate results.

4-02. TRANSMISSION LOSS OF WALLS. Paragraph 4-01 above considered the distribution of sound inside a room that contains the sound source. Next it is essential to know the amount of sound that escapes from that room into adjoining spaces by way of the walls of the room containing the sound source.

a. "The Mass Law". When a sound wave strikes the "front" surface of a solid wall, there is enough energy in the tiny pressure oscillations in the air to cause the whole wall to vibrate. If the wall is relatively lightweight, it will be set into vibration more easily than if it is heavyweight. In vibrating as a whole, this wall sets into oscillation the air particles along its "rear" or opposite surface. These vibrating air particles radiate as sound energy into the space on this rear side of the wall. Thus, an incident sound wave excites the front side of the wall, and the wall re-radiates the sound wave from its rear side. (If the wall is at all porous, some sound, i.e., oscillating air particles, can actually pass through the pores of the wall.)

It is generally true that a lightweight wall will be more easily excited by an incident sound wave than will a heavyweight wall and therefore will "transmit" more radiated energy to the other side. This generalization gives rise to the effect known as "the mass law" in acoustics. To a first approximation, "the mass law" suggests that for each doubling of the surface weight of the wall there will be about 5 or 6 dB less transmitted sound. The mass law also suggests that for each doubling of the frequency of the sound there will be about 5 or 6 dB less transmitted sound. There are some qualifications to these generalities which will not be discussed here, but the "transmission loss" data given in the tables reflect these effects.

b. Transmission Loss (TL). The approximate "transmission loss" or "TL" values, expressed in dB, of a number of typical wall constructions are given in Tables 21-31.

Table No.	Construction Material
21	Solid, dense concrete or masonry
22	Hollow-core concrete or masonry
23	Stud-type partitions
24	Metal panel partition and industrial acoustic doors
25	Glass walls or windows
26	Double-glass construction
27	Wood or plywood, including 2 in. thick solid wood door
28	Plaster
29	Aluminum
30	Steel
31	Lead

The values given in these tables encompass many more materials than normally required for straight-forward noise control problems, but they are offered for the benefit of the architect or engineer who might wish to consider certain special designs or applications. They are included also to show that certain lightweight wall materials cannot adequately confine the high noise levels of some mechanical equipment.

It is important to realize that the TL of a wall is merely the ratio, expressed in decibels, of the sound transmitted by a wall to the airborne sound incident upon the wall. Thus, the TL of a wall is a performance characteristic that is entirely a function of the wall weight and material, and its numerical value is not influenced by the acoustic environment on either side of the wall or the area of the wall.

c. Noise Reduction ("NR"). The total effectiveness of a wall or partition involves both the TL of the wall and certain other factors associated with the geometry and the acoustic characteristics of the "receiving room" (the room into which the noise is transmitted). These factors are reasonably self-evident. For example, it is probably obvious that a wall with a relatively small area will transmit less total noise energy than will a wall with a relatively large area, even though each square foot of the wall has the same TL value. Also, it is probably obvious that the sound level in the "receiving room" will be influenced by the amount of acoustic absorption in the receiving room; that is, the SPL will be relatively high in a "live" receiving room having little or no acoustic absorption whereas it will be relatively low in a "dead" receiving room having large amounts of acoustic absorption.

Thus, when noise travels through a wall from one room (the "source room") to an adjoining room (the "receiving room"), three factors are involved: (1) the TL of the wall, (2) the area of the wall that is common to both rooms and that is transmitting the noise, and (3) the acoustic characteristics of the receiving room that receives the transmitted noise. The term "noise reduction" of a wall (abbreviated to "NR") is the term that includes all three of these factors. In the manual, the area of the common transmitting wall and the acoustic characteristics of the receiving room are combined into a single term, called here "the wall correction term" and designated as "C" in the equation:

$$NR = TL + C$$

For this equation, values of TL are found in Tables 21-31 and values of C are found in Table 32. The "noise reduction" of that specific wall between the transmitting room and the receiving room is now known. The SPL in the receiving room can then be determined from

$$SPL_{\substack{\text{source}\\ \text{room}}} - NR = SPL_{\substack{\text{receiving}\\ \text{room}}}$$

since the SPL in the source room can be calculated from the procedures given in Paragraph 4-01 above.

The "wall correction term" C in Table 32 depends on the ratio S_w/R_2, where S_w is the area in sq ft of the common wall between the two rooms and R_2 is the Room Constant of the receiving room. This Room Constant can be determined from Table 19 and Figure 12.

<u>d</u>. <u>Example: Control Room in MER.</u> It now seems appropriate to illustrate all of the material up to this point in the manual with an example. Suppose a glass-walled Control Room is to be located at one end of a mechanical equipment room that houses some refrigeration and pumping equipment for a building. The MER is 80 ft long, 40 ft wide and 20 ft high and has a 2 in. thick acoustic and thermal insulation treatment applied directly to its entire ceiling area. Assume the NRC (noise reduction coefficient) of the material is 0.80. The Control Room is 20 ft long, 12 ft wide and 8½ ft high. It has an acoustic tile ceiling supported on a suspension system that provides an

18 in. air space above the ceiling. Suppose this ceiling combination has an NRC of 0.85 according to the Acoustical and Insulating Materials Association Bulletin. The 20 ft dimension of the Control Room lies along the 40 ft width of the MER and a ¼ in. thick glass wall is planned as the common wall extending from the floor line to an 8 ft height. The glass wall is approximately 60 ft from a 1500-ton centrifugal compressor, 40 ft from a 450-ton centrifugal compressor, 20 ft from a 100-ton reciprocating compressor, and 50 ft from a group of 4 motor-driven 50-HP pumps (1750 RPM). It is desired to know the SPL in the Control Room and to determine the nature of speech communication possible within the Control Room when all the equipment is in operation.

The volume of the MER is 80x40x20=64,000 cu ft and the total interior surface area is 11,200 sq ft. The area of the ceiling acoustic treatment is 3200 sq ft which amounts to 29% of the total room area. According to Table 19A and Figure 12, this room has a Room Constant of approximately 3000 sq ft at 500-8000 Hz. According to Table 19B, the Room Constant at lower frequency is

600 sq ft at 31 Hz
900 sq ft at 63 Hz
1500 sq ft at 125 Hz
2400 sq ft at 250 Hz

The area of the glass wall (S_w) separating the two rooms is 20x8=160 sq ft. From Table 32, values of C can be determined for the various ratios of S_w/R_2. These are summarized in Table A immediately below.

TABLE A

Octave Band (Hz)	Common Wall Area S_w	Receiving Room Constant R_2	Ratio S_w/R_2	C from Table 32 (dB)
31	160	50	3.2	-5
63	160	75	2.1	-4
125	160	125	1.3	-2
250	160	200	.80	0
500-8000	160	250	.64	+1

The TL of ¼ in. thick glass can be found in Table 25, and the NR for this glass wall can then be determined from the relationship

$$NR = TL + C$$

This is summarized in Table B immediately below.

TABLE B

Octave Band (Hz)	TL ¼ in. glass (dB)	C (dB)	NR (dB)
31	5	-5	0
63	11	-4	7
125	17	-2	15
250	23	0	23
500	25	1	26
1000	26	1	27
2000	27	1	28
4000	28	1	29
8000	30	1	31

In Table C below, the SPLs of the three compressors are given, both at the normalized 3-ft distance as obtained from Table 4, and at the 20, 40 and 60-ft distances when extrapolated in accordance with the differences in REL SPL as found in Figure 11 or in simplified Table 20 (using the Room Constants for the MER of 600 to 3000 sq ft for the different frequencies).

TABLE C

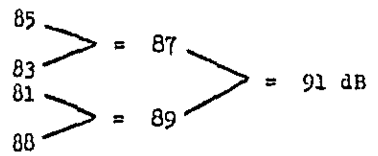
Octave Band (Hz)	SPL 1500-Ton Centrifugal Compressor		SPL 450-Ton Centrifugal Compressor		SPL 100-Ton Reciprocating Compressor	
	3 ft	60 ft	3 ft	40 ft	3 ft	20 ft
31	89	85	87	83	85	81
63	90	84	88	82	90	85
125	91	84	89	82	89	83
250	92	83	90	82	92	85
500	93	83	90	80	93	85
1000	97	87	91	81	92	84
2000	99	89	92	82	90	82
4000	94	84	87	77	86	78
8000	87	77	80	70	81	73

In Table D on the next page, the SPLs of a 50-HP motor and a 50-HP pump are first given at 3-ft distance. The higher value in each octave band is then taken to arrive at the SPL of the combination at 3-ft distance. This is then extrapolated to the 50-ft distance. Finally the total SPLs are given for all four motors and pumps (6 dB greater than for one motor-pump, according to Step 2 of Table 18). Again, the MER Room Constant has the values 600, 900, 1500, 2400, and 3000 sq ft for the various frequencies.

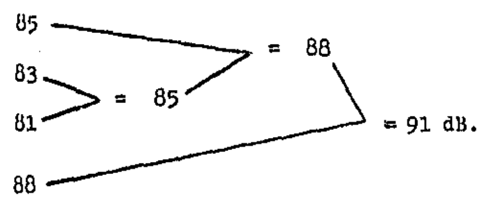
TABLE D

Octave Band (Hz)	SPL at 3 ft			SPL at 50 ft	
	Motor	Pump	Pair	One Pair	Four Pairs
31	82	86	86	82	88
63	83	86	86	80	86
125	87	89	89	82	88
250	91	91	91	83	89
500	92	91	92	83	89
1000	92	89	92	83	89
2000	91	86	91	82	88
4000	85	83	85	76	82
8000	78	78	78	69	75

In Table E below, the individual SPL contributions of Table C and D are combined, by decibel addition, to obtain the total SPL at the glass wall of the Control Room. To illustrate the decibel addition, in accordance with Step 1 of Table 18, the four individual SPLs at 31 Hz can be added as follow:



or, adding the same numbers, by a different sequence



Sometimes, addition by different sequences will produce variations of 1 dB in the final total. This is within the accuracy of the simple (easy-to remember) rules of Table 18. In Table E, all other octave band totals are listed.

TABLE E

Octave Band (Hz)	SPL 1500-Ton Compressor at 60 ft	SPL 450-Ton Compressor at 40 ft	SPL 100-Ton Compressor at 20 ft	SPL 4 50-HP Motor-Pumps at 50 ft	Total SPL in MER at Glass Wall
31	85	83	81	88	91
63	84	82	85	86	90
125	84	82	83	88	91
250	83	82	85	89	91
500	83	80	85	89	91
1000	87	81	84	89	92
2000	89	82	82	88	92
4000	84	77	78	82	87
8000	77	70	73	75	80

Now, knowing the SPL on the MER side of the glass wall (from the last column of Table E) and the NR of the glass wall (from the last column of Table B), the SPL inside the Control Room can be estimated from

$$SPL_{\substack{\text{receiving}\\ \text{Room}}} = SPL_{\substack{\text{source}\\ \text{room}}} - NR$$

This is shown in Table F:

TABLE F

Octave Band (Hz)	SPL in MER at Glass Wall	NR of Glass Wall	SPL in Control Room	
31	91	0	91	
63	90	7	83	
125	91	15	76	
250	91	23	68	
500	91	26	65	PSIL
1000	92	27	65	= 65 dB
2000	92	28	64	
4000	87	29	58	
8000	80	31	49	

This Control Room will have a "speech interference level" of approximately 65 dB, and according to Table 3 this would permit reliable speech communication with a raised voice at 3-ft distance, a very loud voice at 6-ft distance, or shouting at an 11-ft distance. There would be no hearing damage problem, as may be seen by comparing the Control Room SPLs with Tables 1 or 2 in the PPA Manual (Table 2 would be applicable because the centrifugal compressors and motors would probably produce pure tone signals). If there were no glass-wall enclosure for the Control Room, the noise levels would reach 87 to 92 dB in the upper frequency bands and these would be a cause for concern for occupants stationed in the Control Room area.

It is of interest to note at this point the acoustic value of the 2-in. thick acoustic and thermal insulation material placed in the ceiling of the MER. For a brief comparison, suppose that no acoustic absorption were used in the MER. Recall that the volume of the MER in this example is 64,000 cu ft and that the total interior surface area is 11,200 sq ft. From Table 19A and Figure 12, the MER is now found to have a Room Constant of approximately 500 sq ft at 500-8000 Hz. At the lower frequencies, according to Table 19B,

0.2 R = 100 sq ft at 31 Hz
0.2 R = 100 sq ft at 63 Hz
0.3 R = 150 sq ft at 125 Hz
0.5 R = 250 sq ft at 250 Hz

In Table G on the next page, the SPL of the 1500-Ton centrifugal compressor at 3-ft distance is given in Column 2. These 3-ft values are reasonably independent of the use of absorption in the room (not exactly true but acceptable for the purposes of the manual). In Column 3, the SPLs at 60-ft distance are given for the original condition, using the ceiling absorption material (these values are taken from the third column in Table C). In Column 4, the SPLs at 60-ft distance are shown for the assumed condition of no acoustic absorption in the MER. Comparison of Columns 3 and 4 shows that the use of absorption material reduces the noise levels of the 1500-Ton compressor by 3-6 dB in the middle and high frequency region, as heard at a 60-ft distance. For shorter distances, the improvement due to the absorption material decreases.

TABLE G

Col 1 Octave Band (Hz)	Col 2 SPL at 3-ft distance	Col 3 SPL at 60-ft with absorption	Col 4 distance: without absorption
31	89	85	88
63	90	84	89
125	91	84	90
250	92	83	90
500	93	83	89
1000	97	87	93
2000	99	89	95
4000	94	84	90
8000	87	77	83

e. Example: Office beside MER. Now, assume the same size and arrangement of rooms as studied in the example above, but consider here that an office is to be located where the Control Room was located in the above example. Then, instead of a glass wall, assume a 10-in. thick solid, dense concrete block wall separating the office from the MER. Assume the same equipment and SPLs in the MER and the same acoustic treatment of both rooms. Then, calculate the SPLs to be expected for the office and determine if this would be suitable for office space.

In Table H below, the TL of 10-in. solid concrete block is given (from Table 21), followed by the wall correction term and the ultimate NR of this wall.

TABLE H

Octave Band (Hz)	TL 10-in. solid concrete (dB)	C (dB)	NR (dB)
31	34	-5	29
63	35	-4	31
125	37	-2	35
250	40	0	40
500	45	1	46
1000	52	1	53
2000	58	1	59
4000	63	1	64
8000	68	1	69

In Table J, the SPL in the office is summarized knowing that

$$SPL_{office} = SPL_{MER} - NR_{wall}$$

TABLE J

Octave Band (Hz)	SPL in MER at Wall	NR of Concrete Wall	SPL in Office	NC-35 Noise Criterion
31	91	29	62	--
63	90	31	59	60
125	91	35	56	52
250	91	40	51	45
500	91	46	45	40
1000	92	53	39	36
2000	92	59	33	34
4000	87	64	23	33
8000	80	69	11	32

In Table J, the airborne noise levels in the office are compared with the noise levels that would meet an NC-35 noise criterion. The office noise levels are seen to exceed the NC-35 condition by as much as 6 dB in the 250 Hz band. These levels would be acceptable for an area permitting an NC-40 to NC-45 criterion, such as illustrated by Category 5 areas in Table 2, but these levels would not be recommended for an office that should have an NC-30 to NC-35 acoustic environment. A corridor between the MER and an office would give the desired additional noise reduction required to meet an NC-25 to NC-35 area, provided adequate vibration isolation of the equipment is accomplished.

The office area could be made a bit quieter by use of additional acoustic design, but in practice the extra treatments might be more expensive than desired. The additional treatment, if preferred, could involve the use of (1) more acoustic absorption in both the MER and the office space, (2) a smaller wall area (S_w) common to both rooms, and (3) a still heavier single wall or a special double wall construction between the rooms. Actually, it is believed that rearrangements in the use of the space immediately surrounding the MER would be more economical and practical.

f. Doors and Windows. It is fairly obvious that a poorly-fitted lightweight door or a large lightweight window might constitute a weak link in an otherwise acoustically good wall. When a wall must serve an important acoustic need, then the door or window must be carefully selected to be compatible with the total need of the wall.

Because the area of a door or window is usually quite a small part of the total area of a wall, the TL of the door or window can be lower than that of the wall by certain specified amounts without seriously jeopardizing the acoustic effectiveness of the wall. In Table 33, the reduction in TL of a wall is given for a range of areas of doors and windows and for a relative TL of the door or window compared to that of the wall. As an example, suppose that a wall has a TL of 40 dB at a particular frequency and that a door has a TL of 20 dB at the same frequency. Suppose the door area is 5% of the total wall area. In Table 33, it is found for this combination of conditions that the wall TL would be reduced by 8 dB by this door. Thus, the composite wall-door combination would have an effective TL of 40-8=32 dB.

To minimize the loss of effectiveness of a wall, the door or window should be of the smallest possible area and of the largest possible TL. Doors should be gasketed and provided with a drop strip in order to minimize air leakage paths, and windows should be sealed closed. For massive single walls or for special double walls, double doors or windows should be used and large air spaces should be provided between the doors and windows. The approximate TL of a 2-in. solid wood door, gasketed around all edges, is given in Table 27 (see Footnote 2), and the approximate TLs of a 4-in. thick and a 6-in. thick industrial type "acoustic door" are given in Table 24. The approximate TLs of single thicknesses of glass are given in Table 25 and the TLs of a few double-glass combinations are given in Table 26.

In many situations, the structural requirements will exceed the acoustical requirements of a wall, in which case the door or window can have a TL much lower than that of the wall. A few generalizations are listed below that should aid in the selection of a door or window that will be somewhat acoustically compatible with the wall:

(1) Where the acoustic design requires a minimum, simple, single wall construction, such as conventional stud partitions, movable metal partitions or 4-in. or 6-in. hollow-core concrete block, use ungasketed hollow-core wood doors or ungasketed metal panel doors and minimum ¼ in. thick glass windows.

(2) Where the acoustic design requires somewhat more than minimum wall construction (such as staggered stud construction, 4-in. or 6-in. solid core concrete or masonry, or acoustically filled metal panel partitions), use gasketed solid-core wood doors, or minimum 1-3/4 in.

hollow metal doors packed with dense mineral or glass fiber, or special 1-3/4 in. thick acoustic doors with gasketing, and use windows of minimum area made up of double panes of at least 1/4 in. thick glass with at least 2 in. air space, or windows of larger but limited area made up of double panes of at least ¼ in. thick glass with 4-in. to 6-in. air space.

(3) Where stringent acoustic requirements must be met, adhere to the door or window TL requirements given above as a function of percent area of the total wall. Use special acoustic doors or provide "sound locks" with gasketed double doors, where the doors are spaced at least 5 to 6 ft apart in an acoustically lined vestibule or corridor. Use double glass windows with maximum possible air space and glass thickness and minimum practical area. For slight improvement, the panes may be tilted relative to one another and the interior surfaces of the window framing can be given an acoustic lining.

(4) Where doors are obvious leakage paths for unwanted noise, locate them in positions that will provide minimum disturbance or maximum distance from the important work area of the room, and provide acoustic absorption in the room.

Table 33 can also be used to determine the effective TL of a wall made up of two different portions, where the two portions have different TLs, such as in a 10 in. thick poured solid concrete wall having a knock-out panel of 6 in. thick concrete block.

g. Double Walls. If MERs are bordered by work spaces where a moderate amount of noise is acceptable (such as areas of Categories 5 and 6 and possibly in some cases Category 4 of Table 2), the equipment noise usually can be adequately contained by heavy concrete walls of single thickness. Double walls of concrete can be used to achieve even greater values of TL. For example, two 8-in. thick solid-core concrete block walls separated with an 8-in. air space and structurally not connected together at any point (based on separate footings) would have TL values about 5 dB higher in the low frequency region, 10 dB higher in the middle frequency region and 15 dB higher in the high frequency region than a single 12-in. thick solid-core concrete block wall. Various intentional and unintentional structural connections between double walls have highly varying effects on the TL of double walls, however. For this reason, TL data are not quoted for double walls. In practice, double walls will give a worthwhile improvement over single walls if one of the double walls can be placed on separate footings (for an on-grade location) or on a 1-in. or 2-in. thick layer of construction cork (for upper floor locations), and if the two walls can have a minimum of structural ties between themselves. The improvement will be greatest at high frequency. The air space between the walls should be as large as possible to enhance the low frequency improvement. An obvious extension of the double wall is the wide corridor, with an acoustically treated ceiling. This is recommended as a separator between a noisy MER and a Category 2-4 area and possibly a Category 1 area of Table 2. For close locations of acoustically critical areas to noisy MERs, it is essential that adequate vibration isolation be incorporated in all the suspect machinery and piping. If a Category 1 area (NC-20 to NC-25) is to be located very near a noisy MER, it would be advisable to have an acoustical engineer check the details of the designs.

It is sometimes possible to enhance the TL of a simple concrete block wall or a stud-type partition by resiliently attaching to that wall or partition additional layers of plaster skin, possibly mounted on spring clips that are installed off 1-in. or 2-in. thick furring strips, with the resulting air space filled with acoustic absorption material. These constructions become rather sophisticated and a bit expensive, but they can provide an improvement in TL of 5-10 dB in the middle frequency region and 10-15 dB in the high frequency region, when properly executed.

4-03. TRANSMISSION LOSS OF FLOOR-CEILING COMBINATIONS. Many mechanical equipment areas are located immediately above or below occupied floors of buildings. Airborne noise and structure-borne vibration radiated as noise may intrude into these occupied floors if adequate controls are not included in the building design. The approximate "TL" and "NR" are given here for five floor-ceiling combinations frequently used to control airborne machinery noise to spaces above and below the MER.

None of the data apply for equipment installations mounted on framed wood flooring or on typical lightweight metal deck with 2-3 in. thick concrete surface. These floor constructions are not stiff enough or massive enough to provide good airborne noise control or to support heavy machinery or to give an adequate base for a vibration isolation mounting system.

The five floor-ceiling combinations are discussed in the following paragraphs. All floor slabs are assumed to be of <u>dense concrete</u> (140-150 lb/cu ft density) or of such extra thickness of less dense concrete to give the equivalent surface weight of the specified dense concrete.

<u>a</u>. <u>Type 1 Floor-Ceiling.</u> This combination is made up of a concrete floor slab with or without acoustic tiles or panels cemented

directly to the underside of the slab. It is important to realize that the acoustic tiles add nothing to the transmission loss of the floor slab. The acoustic tiles only provide acoustic absorption in the room in which they are located and hence provide a degree of noise reduction in the room. The estimated TL of a Type 1 floor-ceiling is given in Table 34 for a few typical floor slab thicknesses.

b. Type 2 Floor-Ceiling. This floor-ceiling combination consists of a concrete floor slab below which is suspended a typical low density acoustic tile ceiling in a mechanical support system. To qualify for Type 2 combination the acoustic tile should be not less than 3/4 in. thick, and it should have a Noise Reduction Coefficient ("NRC") of at least 0.65 (when mounted as specified by the Acoustical and Insulating Materials Association). The air space between the suspended ceiling and the concrete slab above should be at least 15 in., but the TL improves if the air space is larger than this. The estimated TL of a Type 2 floor-ceiling is given in Table 35 for a few typical dimensions of concrete floor slab thickness and air space.

c. Type 3 Floor-Ceiling. This floor-ceiling combination is very similar to the Type 2 combination, except that the acoustic tile material is of the "high TL" variety. This means that the material is of high density and usually has a foil backing to decrease the porosity of the back surface of the material. (Ask the acoustic tile representative to identify his "high TL" material.) An alternative version of the Type 3 combination includes a suspended ceiling system of lightweight metal panel sandwich construction consisting of a perforated panel on the lower surface and a solid panel on the upper surface, with acoustic absorption material between. The minimum "NRC" for the Type 3 acoustic material must be 0.65. The estimated TL of a Type 3 floor-ceiling is given in Table 36 for a few typical dimensions of concrete floor slab thickness and air space.

d. Type 4 Floor-Ceiling. The Type 4 floor-ceiling combination consists of a concrete floor slab, an air space, and a resiliently supported plaster ceiling. This combination is for use in critical situations where a high TL is required. The plaster ceiling should have at least 1 in. thickness of high density plaster (minimum 12 lb/sq ft surface weight) and the air space should be at least 18 in. thick. The ceiling should be supported on resilient ceiling hangers that provide at least 1/10 in. static deflection under load. Neoprene-in-shear or compressed glass fiber hangers can be used, or steel springs can be used if they include a pad or disc of neoprene or glass fiber in the mount. A thick felt pad hanger arrangement can be used if it meets the static deflection requirement. The hanger system must not have metal-to-metal short-circuit paths around the isolation material of the hanger.

Where the plaster ceiling meets the vertical wall surface, the perimeter edge of the ceiling must not make rigid contact with the wall member. A ¼-in. open joint should be provided at his edge, which is filled with a non-hardening caulking or mastic or fibrous packing after the ceiling plaster is set.

The estimated TL of a Type 4 floor-ceiling combination is given in Table 37 for a few typical dimensions of floor slab, air space and ceiling thicknesses. It is cautioned that this combination is for use in critical situations, and special care must be exercised to produce a good, resiliently supported, non-porous dense ceiling. Acoustic tile can be added to the underside of the plaster ceiling but it will not change the transmission loss of the combination; it will only add to the acoustic absorption of the room.

e. Type 5 Floor-Ceiling. The Type 5 floor-ceiling combination is the same as the Type 4 combination, except that a "floating concrete floor" is mounted on top of the structural floor slab. The floating concrete floor should not support any large operating equipment. It should extend over that part of the mechanical floor area within 20 ft of any vibration isolated concrete inertia bases carrying specific pieces of noisy operating machinery. The floating concrete floor should be supported off the structure floor at a height of at least 2 in. with the use of properly spaced blocks of compressed glass fiber or multiple-layers of ribbed or waffle-pattern neoprene pads or steel springs (in series with two layers of ribbed or waffle-pattern neoprene pads). The density and loading of the compressed glass fiber or neoprene pads should follow the manufacturers' recommendations. If steel springs are used, their static deflection should not be less than ¼ in. The 2 in. space between the floating slab and the structure slab should be covered with a 1-in. thickness of low-cost glass fiber or mineral wool blanket of 3 to 4 lb/cu ft density. Around all the perimeter edges of the floating floor (around the walls and around all concrete inertia bases within the floating floor area) there should be 1 in. gaps that are later packed with mastic or fibrous filling and then sealed with a waterproof non-hardening caulking or sealing material. A curb should be provided around the perimeter of the floated slab to help discourage water leakage into the sealed perimeter joints, and several floor drains should be set in the structure slab under the floating slab to provide run-off of any water leakage into this cavity space.

As with the Type 4 combination, the Type 5 combination includes a resiliently supported plaster ceiling under the structure slab. The estimated TL of a Type 5 floor-ceiling combination is given in Table 38 for a few typical dimensions of floating floor slab in combination with the Type 4 structures of Table 37. It is to be noted that the floating slab is intended to improve the airborne TL of a floor; it is not suggested here as a vibration isolation mounting base for large equipment, although it will provide certain benefits to some structure-borne noise or pipe supports, duct supports, drainage lines, electrical conduit and the like. The floating slab may also be used with the Types 1-3 floor-ceiling combinations; see the note at the bottom of Table 38.

As a general rule, to be reinforced later in the section under vibration isolation, the MER structural floor slab for an upper floor in a multi-floor building should not be less than 6 in. thick for completely rotary-action equipment, nor less than 8 in. thick for reciprocating-action equipment. These suggestions are based on acoustic considerations only and are not intended to represent structural requirements of the building. Even thicker floor slabs will be more beneficial acoustically. Where possible, large equipment should be located over principal or secondary beams in the flooring layout.

In the upper frequency bands of Tables 34-38, extremely high TL values (say, anything above 60 or 65 dB) are indicated as possible. In practice, these values cannot be achieved without making a real concentrated effort to stop all escape paths of airborne and structure-borne noise.

f. Noise Reduction of Floor-Ceiling Combinations. Paragraph 4-02.c. discussed the conversion of transmission loss of a wall into the noise reduction of a wall by use of the "wall correction term", designated by the letter "C" in Table 32. The same type of correction must be applied to convert the TL of a floor-ceiling combination to its NR value. This applies, of course, to the situation in which the MER is immediately above or below an adjoining area of concern. For identification purposes, the term is called "floor correction term" here, but it is represented by the same letter "C" and it is also obtained from Table 32, based on (1) Room Constant, and (2) common floor-ceiling area of the receiving room. The value of "C" will differ, of course, from room-to-room, so it must be redetermined for each room of interest above, below or beside a machine room.

In the equipment noise summary tables, SPLs are given at 3-ft distances from the equipment. These values should be used as the source room SPLs in the relationship

$$SPL_{\substack{\text{source}\\\text{room}}} - NR = SPL_{\substack{\text{receiver}\\\text{room}}}$$

when estimating noise levels in areas on the floor immediately below the equipment. However, it would be cautioned that the 3-ft SPLs are fairly localized values and they drop off with distance from the unit. Thus, the SPLs calculated for the receiving room below would apply immediately beneath the equipment and would drop off with distance away from that location. In fact, it can be expected that the SPLs below will be generally somewhat lower than the calculations would indicate, depending on receiving room size, the value of S_w used in the calculation and possibly the floor area occupied by the equipment in the MER.

4-04. SOUND DISTRIBUTION OUT-OF-DOORS. There are three types of conditions in which outdoor equipment may be of concern. This assumes that all equipment except cooling towers, evaporative or air-cooled condensers and some transformers will be housed within a building. The three conditions are: (1) cooling tower or transformer noise radiated to nearby neighbors, (2) close-in cooling tower noise that enters its own building through the wall or roof deck immediately beside the tower, and (3) escape of machinery room noise to the outdoors through ventilation openings in the MER walls. These are discussed separately in the paragraphs that follow.

<u>a</u>. <u>Cooling Tower Noise to Neighbors.</u> In the Power Plant Acoustics Manual, considerable attention was given to outdoor propagation of sound under Paragraph 5-06 (pages 67-75) and to the derivation of outdoor noise criteria for neighbors under Paragraph 3-06 (pages 16-18). A procedure for combining that material was then summarized in DA Forms 3452-12 and 3452-13 of the PPA Manual. That material is directly applicable to the outdoor cooling tower noise problem. It is not repeated here in its entirety, but the key steps are outlined.

1. Fill out DA Form 3452-12 to obtain the outdoor SPLs at the neighbor's location that are believed to be acceptable to the neighbor.

2. Fill out DA Form 3452-13 to obtain the PWL of a cooling tower that would yield the acceptable SPL values.

3. From Tables 6 and 7 of this manual, determine the PWLs of the proposed cooling tower (or towers).

4. If the cooling tower orientation is known, the appropriate directionality corrections of Table 10 of this manual can be applied to the PWL values. These corrected values would then represent the equivalent PWL of the sound radiated in that particular direction toward the neighbor.

5. These corrected PWL values should be compared with the PWL criterion of Step 2 above. If the PWL values are less than the PWL criterion in all octave bands, there will probably be no noise problem. If the PWL values are greater than the PWL criterion in any octave bands, there may be a noise problem. If the noise excess is less than 10 dB, the building owner may choose to "take a chance" on "getting by" with the noise, but some practical remedial measure should be planned in the event that it may later be required. If the noise excess is over 10 dB, it would be wise to consider definite remedial steps before the cooling tower is installed. These steps could include a relocation of the cooling tower, a re-orientation of the cooling tower, use of a quieter cooling tower, intentional cycling to a lower fan speed during the acoustically critical periods, or installation of intake and/or discharge mufflers to quiet the noise to acceptable limits.

In the above step-by-step procedure, DA Form 3452-13 could be by-passed if desired. Instead, the cooling tower SPL can be calculated for the neighbor's distance and direction with the use of Tables 6-10. The calculated SPL (corrected for any other attenuation effects, such as listed in Items 4-6 of DA Form 3452-13) may then be compared with the outdoor SPL criterion derived in DA Form 3452-12. Noise excesses should be considered as in Step 5 above.

b. Example. Suppose two 50-HP propeller-type induced draft cooling towers are to be located on the ground near the power plant of a military base at a site approximately 400 ft from a hospital building. The hospital has several patients' rooms on the third and fourth floors that have direct line-of-sight to the cooling towers. The rooms have normally open windows when weather permits. Will the cooling tower noise be acceptable for patients in the hospital and if not, what alternatives should be planned?

A filled-in sample copy of DA Form 3452-12 is given on the following page. It shows a reasonable "final outdoor SPL criterion" for this situation.

The SPLs of the cooling towers are calculated in Table K for a distance of 400 ft, using Tables 6 and 9. Assuming that the cooling towers can be oriented to give minimum noise radiation in the direction of the hospital building, the SPL corrections of Table 10 are then applied for a "side" of the tower.

TABLE K

Octave Band (Hz)	PWL 100-HP C.T.	Distance Term for 400 ft	AVG SPL 400 ft	Correction for side of C. T.	Est. SPL 400 ft
31	108	50	58	-2	56
63	113	50	63	-2	61
125	113	50	63	-2	61
250	108	50	58	-3	55
500	105	50	55	-4	51
1000	101	51	50	-4	46
2000	98	51	47	-5	42
4000	95	53	42	-6	31
8000	90	56	34	-6	28

Comparison of the bottom line of DA Form 3452-12 with the right-hand column of Table K reveals that the cooling tower noise exceeds the desired criterion by 6-8 dB in the 125-4000 Hz bands. Several approaches are possible at this point. On one hand, a 6-8 dB excess might suggest a "wait and see" attitude toward later noise control. On the other hand, once the tower is installed and if it truly is too noisy, then expensive baffles or barriers or closed windows (possibly requiring

DA FORM 3452-12

CRITERION SPL FOR CRITICAL NEIGHBOR

CRITICAL NEIGHBOR HOSPITAL PATIENT

CRITICAL TIME: DAY ☐ NIGHT ☑

FREQUENCY BAND IN CPS								
31	63	125	250	500	1000	2000	4000	8000

1. OUTDOOR BACKGROUND SPL AT NEIGHBOR (FROM BACKGROUND MEASUREMENTS OR FROM TABLE 7 AND FIG. 10)

SUPPOSE CURVE 3 OF FIG. 10 OF P.P.A.

31	63	125	250	500	1000	2000	4000	8000
–	53	48	43	38	33	29	25	23

2. LET ~~PLANT~~ COOLING TOWER NOISE EXCEED BACKGROUND BY 5 dB (SEE PARAGRAPH 3-06 b FOR DISCUSSION)

3. TENTATIVE OUTDOOR SPL CRITERION (ITEM 1 + ITEM 2)

31	63	125	250	500	1000	2000	4000	8000
–	58	53	48	43	38	34	30	28

4. RECOMMENDED INDOOR SPL CRITERION FOR NEIGHBOR FROM TABLE 6: "NC- 25 "

5. OCTAVE BAND SPL FOR ITEM 4 "NC" CURVE FROM FIG. 9

31	63	125	250	500	1000	2000	4000	8000
	54	44	37	31	27	24	22	21

6. APPROXIMATE NOISE REDUCTION PROVIDED BY ~~NEIGHBOR'S~~ HOSPITAL BUILDING, FROM TABLE 51 ~~OR SEPARATE STUDY~~ OF P.P.A.

31	63	125	250	500	1000	2000	4000	8000
8	9	10	11	12	13	14	15	16

7. TENTATIVE OUTDOOR SPL CRITERION (ITEM 5 + ITEM 6)

31	63	125	250	500	1000	2000	4000	8000
–	63	54	48	43	40	38	37	37

8. FINAL OUTDOOR SPL CRITERION. LOWER SPL IN EACH OCTAVE BAND FROM ITEMS 3 AND 7

31	63	125	250	500	1000	2000	4000	8000
–	58	53	48	43	38	34	30	28

room air conditioning) might be required to reduce the cooling tower noise. Thus, if at all possible, move the cooling tower location to a distance of at least 600-800 ft, or position the cooling tower so that some other building (such as the power plant building in this example) serves as an acoustic barrier between the towers and the hospital. If practical, some nighttime noise reduction could be obtained with reduced fan speed (see Paragraph 3-10. d.)

If there is no alternative short of installing sound barriers or mufflers, refer to Table 48 of PPA for barrier attenuation data and to Tables 35-41 of PPA for attenuation of various muffler configurations. Cooling towers must have free-flow of large quantities of air, so very large muffler openings and low pressure drops are required. Seek the assistance of reputable muffler manufacturers; do not attempt the design of mufflers alone.

c. Example: Outdoor Transformer Noise. Suppose a particular transformer has a NEMA sound level rating of 80 dBA and that this transformer is to be installed outside a building at a distance of 20 ft from the closed windows of a conference room requiring an NC-30 criterion. There is no assurance that the transformer will be exceptionally noisy but it is desired to provide a barrier wall if there is a possibility that it may be noisy.

Table L summarizes the problem. From Table 16 the expected maximum indoor levels of a transformer are estimated for a 3 ft distance; these are given in Col. 2 of Table L. From Paragraph 3-15. c., a procedure is given for converting the indoor SPL of a transformer to an outdoor SPL (this procedure not applicable to any other equipment); the estimated outdoor levels at 20 ft are listed in Column 3 of Table L. Acceptable SPLs outside the conference room windows are given in Column 4; these values are obtained by arithmetic addition of the NC-30 criterion levels to the noise reduction provided by an exterior wall with closed windows (see Table 51 of PPA). Column 5 of Table L shows a possible noise excess of 10 dB at 250 Hz and 11 dB at 500 Hz.

Table 48 and pages 71-73 of PPA describe the attenuation of barrier walls in terms of two dimensions H (the extension of the wall beyond the line-of-sight between the source and the receiver) and R (the distance from the source to the barrier wall). An attenuation of 10 dB at 250 Hz can be achieved with dimensions such that $H^2/R = 2$ or greater. Thus, a wall placed 4 ft from the transformer and extending at least 3 ft above and beyond the line-of-sight between any part of the transformer and all windows of the conference room will essentially meet the need (ie. $3^2/4 = 9/4 = 2\ 1/4$).

TABLE L

Col.1 Octave Band (Hz)	Col. 2 Transformer SPL: indoors at 3 ft	Col.3 outdoors at 20 ft	Col.4 Acceptable outdoor SPL	Col.5 Noise excess (dB)	Col.6 Attenuation of barrier $H^2/R = 2.0$
31	80	56	--	--	1
63	85	61	76	--	4
125	90	66	68	--	7
250	97	73	63	10	10
500	94	70	59	11	13
1000	89	65	57	8	16
2000	84	60	57	3	19
4000	79	55	58	--	22
8000	74	50	57	--	24

The barrier wall should be solid and have a TL of at least 20 dB at 250 Hz. A 4-in. thick hollow-core dense concrete block wall would meet this TL requirement.

<u>d</u>. <u>Close-in Cooling Tower Noise.</u> If it should be necessary to check against transmission of outdoor cooling tower noise through a nearby wall or the roof deck into a critical area immediately inside the building, the close-in noise levels of Table 11 should be used, and a procedure similar to that of the examples under Paragraphs 4-02.<u>d</u> and <u>e</u> above should be followed. Allowance should be made for the fact that the highest close-in noise levels exist only a few feet around the air intake or discharge and that the noise levels drop off at greater distances. Hence, the average SPLs incident over a large wall or roof area (S_w in the examples referred to) will be lower than the close-in values.

<u>e</u>. <u>Ventilation Openings in MER Wall.</u> When room ventilation air is brought into an MER through a hole in the exterior wall, that hole will allow noise to escape to the outside. The escaping noise may be disturbing to nearby neighbors. In anticipation of such a problem, the PWL of the escaping noise should be calculated and compared with a PWL

criterion for the situation (which can be determined by using DA Forms 3452-12 and 3452-13 as discussed above under cooling tower noise).

The power level of sound that passes through an opening into or out of a room is approximately

$$\text{PWL (in dB re } 10^{-12} \text{ watt)} = \text{SPL} + 10 \log A - 10$$

where SPL is the sound pressure level at or near the opening and A is the cross-section area in sq ft of the opening. A new term "Area Factor" ("AF") is defined as follows:

$$\text{"AF"} = 10 \log A - 10$$

Then

$$\text{PWL} = \text{SPL} + \text{"AF"}$$

Table 39 gives a range of values of "AF" for a representative group of areas. If the PWL of the escaping noise exceeds the PWL criterion, it would be wise to consider use of a noise attenuating muffler in the opening in order to eliminate the excess noise. A muffler manufacturer could provide attenuation data for his products, or estimates could be made using muffler data given in the PPA Manual.

4-05. DATA FORMS. The procedures offered in this manual are summarized in a series of Data Forms, which, when filled in, provide simple and convenient forms for calculation and documentation of most of the acoustical aspects of the mechanical system design for airborne noise control. Blank copies of the Data Forms are given at the rear of the manual under Section VII, and these can be reproduced and used for any particular analysis. The Data Forms are illustrated in the next several pages with specific examples.

4-06 EXAMPLE. In any real-life mechanical equipment room there is usually found a wide assortment of several different pieces of electrical and mechanical equipment. In the present illustration, only a few pieces of equipment are assumed, in the interest of minimizing the quantity of details.

a. Conditions. Assume a Boiler Room at Elevation 100 ft. in an upper floor of an office building as sketched in Figure A. The room is 60 ft long (north to south), 50 ft wide (east to west), and 20 ft high. The north and south walls of the Boiler Room (MER) and the upper 10 ft of the east and west walls are exterior walls of the building. For this example, assume that the occupied spaces to the east and west of the Boiler Room have an internal height of 8 ft and the roof deck is 2 ft above the ceiling. A 100 sq ft damper-controlled ventilation opening is located in both the north and south walls of the MER. The east wall of the room is bounded by a Data Computer Room and the west wall is bounded by a group of offices for the Building Manager and the Building Engineer. Two-inch thick thermal insulation, having an "NRC" of 0.80 is applied to the ceiling of the MER and to approximately 1200 sq ft of wall surface between the MER and the office spaces along its east and west walls. The floor of the MER (at Elevation 100 ft) is of 10-in. thick dense concrete. The floors below the MER are to be used for office suites. The east and west walls of the MER might normally be constructed of 10-in. hollow-core dense concrete, but these are to be checked for adequacy in this design.

There are no nearby neighbors of concern to the south of the building, but a tall un-air-conditioned hotel (with open windows in the summer time) is located 200 ft to the north. A main street runs between the office building and the hotel, carrying nighttime traffic that might be characterized as "continuous light traffic"; and the area might be classified as a "business or commercial area". (These designations are taken from Table 7 of the Power Plant Acoustics Manual.) The Boiler Room contains one 2000 BHP boiler and one 1000 BHP boiler located as shown in Figure A. The room also contains two steam valves and a bank of three 50-HP motor-pump assemblies. To simplify the example only the 2000 BHP boiler, one steam valve and one motor-pump assembly are included in the sample calculations here. These are shown shaded in Figure A. In a true life problem all equipment would be considered. An Operator's Control Room is located in the northeast corner of the room.

Assume the Boiler Room and the adjoining spaces have the following common wall or floor areas:

Control Room (side walls only)

30 ft x 8 ft = 240 sq ft

Data Computer Room

50 ft x 8 ft = 400 sq ft

Manager's and Engineer's Offices (each)

15 ft x 8 ft = 120 sq ft

Secretary's Office and File Room (each)

12 ft x 8 ft = 96 sq ft

Any large typical Office or Conference Room
on the floor below the Boiler Room

15 ft x 20 ft = 300 sq ft floor area

In the case of the Control Room, suppose that 1/4 in. glass walls are planned, if they are found to be adequate, and that a ceiling cover over the Control Room will be of pre-cast 2 in. thick concrete panels (with an acoustic tile ceiling supported below the concrete panels). Assume that each of the adjoining spaces is provided with a mechanically supported acoustic tile ceiling having enough air space above the ceiling to give an NRC value of greater than 0.75.

b. Criterion Assignments. The following criterion assignments are made for all the spaces bordering the Boiler Room or influenced by its noise. Refer to Table 2. Generally, apply the lower limit of the NC range to critical areas and the upper limit of the NC range to non-critical areas in a given category.

Typical Offices at Elevation 90 ft (under the MER):

NC-30

Offices of Building Manager and Secretary at Elevation 100 ft:

NC-35

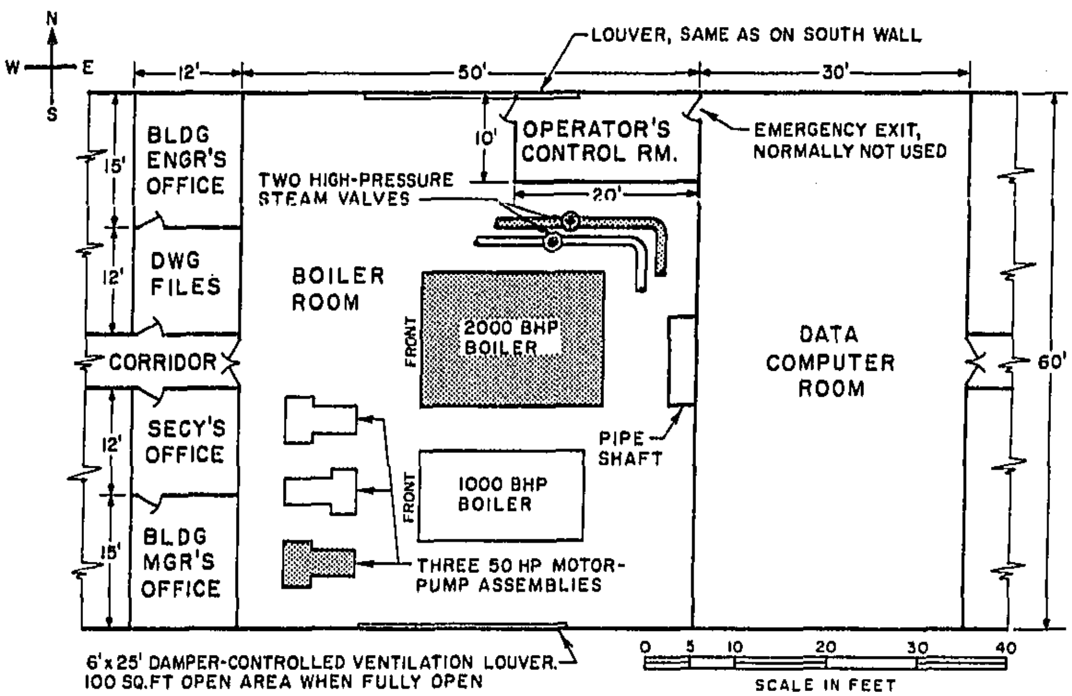


FIG. A INITIAL LAYOUT OF ASSUMED BOILER ROOM AND SURROUNDING SPACES (SAMPLE CALCULATIONS ARE INCLUDED FOR ONLY THE THREE SHADED NOISE SOURCES; ONE BOILER, ONE STEAM VALVE AND ONE MOTOR-PUMP ASSEMBLY)

Building Engineer's Office and Drawing File Room at Elevation 100 ft:

NC-40

Data Computer Room at Elevation 100 ft:

NC-45

Hotel, with open windows, above fairly noisy street:

NC-25

Operator's Control Room:

10 dB below hearing damage levels for pure tone sounds

These criterion assignments are justified somewhat as follows:

(1) For the Offices under the Boiler Room: NC-30. The ventilation system in modern buildings will produce background noise levels in most offices in the general range of NC-30 to NC-35. Thus, if typical offices are located under the Boiler Room and if the mechanical equipment noise can be kept down to an NC-30 condition, there will almost certainly be no serious complaints from the tenants about MER noise. If a very large Conference Room or Meeting Room or an especially critical Office is to be located under the Boiler Room, an NC-25 criterion would be justified for that room.

(2) For the Offices of the Building Manager and Secretary beside the west wall of the Boiler Room: NC-35. In these Offices, prospective tenants may discuss rental details, costs, building facilities, tenant layouts, etc. It would not be conducive to business negotiations for the prospective tenant to be disturbed by the noise from the Boiler Room (even before he moves in). Hence, an NC-35 criterion must be achieved, and an NC-30 would even be desirable. For full time occupancy by the Manager and the Secretary, an NC-35 would certainly be acceptable.

(3) Building Engineer's Office: NC-40. Typically, the Building Engineer is accustomed to a noisy environment, so a quiet private office is almost a luxury. It would not be unreasonable to apply an NC-40 noise criterion to this office and to the File Room beside the office.

(4) Data Computer Room: NC-45. The present-day Computer Room is usually quite noisy due to the operation of various computers and auxiliaries. Even when the equipment is not actively in operation, cooling fans in the equipment racks are usually running and producing a relatively high background. An NC-45 condition is approximately that found in a room served by a window-type air conditioner with the fan set at "low" or "medium" speed. This seems to be a reasonable criterion for Computer Room noise transmitted through the wall from the Boiler Room.

(5) Inside a Hotel Room, across the street, with windows open: NC-25. Street noise at night would probably exceed an NC-25 condition inside the hotel room. Thus, Boiler Room noise probably would not be identifiable inside the hotel room if it can be kept at or below NC-25.

(6) Operator's Control Room. It would be desirable to keep the Control Room noise levels at least 10 dB below the maximum noise levels recommended for hearing conservation based on pure tones, since motors and pumps may generate pure tones. These levels would be 10 dB below the TB MED 251 values given in Table 2 of the Power Plant Acoustics Manual. The reader is referred to pages 8-12 of PPA for a more detailed discussion of this criterion.

The various acoustic design features of the Boiler Room and the surrounding spaces can now be studied with the aid of the Data Forms, identified by "DA Form" numbers in the manual, in keeping with Department of the Army publication practices. To introduce the forms, only parts of the total design are carried to completion. For the sake of simplicity, MER noise to the Data Computer Room and to the Building Manager's Office are evaluated here.

c. DA Form 3452-14-R. This Data Form is used to determine the Room Constant of the source room (the Boiler Room) and the various receiving rooms (the adjoining spaces). On the three pages that follow, sample Data Forms are filled out for the Boiler Room, the Computer Room, and the Building Manager's Office. Four points are noted in regard to DA Form 3452-14-R.

(1) The volume is obviously the length x width x height of the room. The equipment occupies some of this volume, but in the procedures given here that loss of room volume is ignored. Actually, the equipment adds effective surface area to the room, but this is also ignored most of the time. If large ventilation ducts were covered with acoustically absorbent thermal wrappings, that area would be of significant acoustic value and it should be added into the Item 4 data. Also, large pieces of equipment serve as partial obstacles that interfere with uniform sound distribution in a large MER. This is also ignored in the simplified procedure. The total effect of these various factors associated with large rooms and large pieces of equipment is that the actual SPLs are usually a bit lower than the estimated SPLs for large distances from the equipment in question. Only in a very critical problem would it be justified, however, to go into greater detail of each specific room layout.

(2) For many rooms, by this simplified method, the Room Constant obtained in Item 7 may be very nearly equal to the total area of acoustic treatment in the room as given in Item 4. There is a basic difference between these two quantities, however, and the Item 5-7 steps should be carried out.

(3) In some office-type receiving rooms, carpeting may be used and acoustic tile ceilings may not be used. The first footnote of this DA Form provides a means for allowing some room absorption due to carpet and absorptive furnishings.

(4) Where a room has an opening to the outside that will be open most of the time (as for ventilation of an MER), that opening has essentially 100% absorption. That is, all the sound that strikes the opening passes on through and none of it returns. In the case of the Boiler Room, there are two ventilation openings totaling 200 sq ft open area when fully open. Assuming the openings will always be at least 50% open, an area of 100 sq ft is added to all the Room Constant values of Items 7 and 8 to produce the Item 9 values. This extra 100 sq ft will be of little practical value in this particular example, but it may be a significant part of effective absorption in some small rooms that otherwise would have no intentional acoustic treatment. For the Boiler Room in this example, it is added only to illustrate the point. In the DA

DA FORM 3452-14-R, 10 Aug 70

ROOM CONSTANT OF SOURCE ROOM OR RECEIVER ROOM

ROOM NO. OR DESIGNATION BOILER ROOM

1. AVERAGE ROOM DIMENSIONS (IN FT.)
   LENGTH 60 WIDTH 50 HEIGHT 20
2. VOLUME OF ROOM 58,000 CU. FT. ← 2000 CU FT DEDUCTED FOR CONTROL ROOM
3. TOTAL INTERIOR SURFACE AREA OF ROOM 10,400 SQ. FT.
4. AREA OF PLANNED ACOUSTIC TREATMENT+ 4,200 SQ. FT.
5. PERCENT AREA COVERED BY ACOUSTIC TREATMENT 40 %
   (100 x Item 4/Item 3)
6. "ROOM LABEL" FOR ITEM 5 FROM PART A OF TABLE 19
   MEDIUM- DEAD TO DEAD
7. FOR ITEMS 2 AND 6, ROOM CONSTANT FROM FIGURE 12
   R = 4000 SQ. FT. FOR 500 - 8000 Hz
8. CHECK ACOUSTIC ABSORPTION TREATMENT:
   ☐ NONE OR NRC = 0.65 - 0.74 ☑ NRC = 0.75 - 0.85

THEN, FOR 31 Hz	0.2 R =		0.2 R =	800
63 Hz	0.2 R =		0.3 R =	1200
125 Hz	0.3 R =		0.5 R =	2000
250 Hz	0.5 R =		0.8 R =	3200

9. ROOM CONSTANT FOR ALL OCTAVE BANDS, IN SQ. FT.#
   (Repeat appropriate values from Items 7 and 8)
   ADD 100 SQ FT FOR VENTILATION OPENING

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000
900	1300	2100	3300	4100	4100	4100	4100	4100

+Add 50% of floor area to Item 4 if floor is carpeted or has drapes or upholstered furniture. Treat this as NRC = 0.65 material.

#Add to all bands any area always open to the outside, ie having 100% absorption.

DA FORM 3452-14-R, 10 Aug 70

ROOM CONSTANT OF SOURCE ROOM OR RECEIVER ROOM

ROOM NO. OR DESIGNATION DATA COMPUTER ROOM

1. AVERAGE ROOM DIMENSIONS (IN FT.)
   LENGTH 60 WIDTH 30 HEIGHT 8
2. VOLUME OF ROOM 14,400 CU. FT.
3. TOTAL INTERIOR SURFACE AREA OF ROOM 5040 SQ. FT.
4. AREA OF PLANNED ACOUSTIC TREATMENT + 1800 SQ. FT.
5. PERCENT AREA COVERED BY ACOUSTIC TREATMENT 36 %
   (100 x Item 4/Item 3)
6. "ROOM LABEL" FOR ITEM 5 FROM PART A OF TABLE 19
   MEDIUM – DEAD
7. FOR ITEMS 2 AND 6, ROOM CONSTANT FROM FIGURE 12
   R = 1500 SQ. FT. FOR 500 - 8000 Hz
8. CHECK ACOUSTIC ABSORPTION TREATMENT:

   ☐ NONE OR NRC = 0.65 - 0.74 ☑ NRC = 0.75 - 0.85

THEN, FOR 31 Hz	0.2 R =	______	0.2 R =	300
63 Hz	0.2 R =	______	0.3 R =	450
125 Hz	0.3 R =	______	0.5 R =	750
250 Hz	0.5 R =	______	0.8 R =	1200

9. ROOM CONSTANT FOR ALL OCTAVE BANDS, IN SQ. FT.#
   (Repeat appropriate values from Items 7 and 8)

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000
300	450	750	1200	1500	1500	1500	1500	1500

+Add 50% of floor area to Item 4 if floor is carpeted or has drapes or upholstered furniture. Treat this as NRC = 0.65 material.

#Add to all bands any area always open to the outside, ie having 100% absorption.

DA FORM 3452-14-R, 10 Aug 70

ROOM CONSTANT OF SOURCE ROOM OR RECEIVER ROOM

ROOM NO. OR DESIGNATION BUILDING MANAGER'S OFFICE
(SAME FOR BUILDING ENGINEER'S OFFICE)

1. AVERAGE ROOM DIMENSIONS (IN FT.)
   LENGTH 15 WIDTH 12 HEIGHT 8
2. VOLUME OF ROOM 1440 CU. FT.
3. TOTAL INTERIOR SURFACE AREA OF ROOM 792 SQ. FT.
4. AREA OF PLANNED ACOUSTIC TREATMENT+ 180 SQ. FT.
5. PERCENT AREA COVERED BY ACOUSTIC TREATMENT 23 %
   (100 x Item 4/Item 3)
6. "ROOM LABEL" FOR ITEM 5 FROM PART A OF TABLE 19
   AVERAGE TO MEDIUM-DEAD
7. FOR ITEMS 2 AND 6, ROOM CONSTANT FROM FIGURE 12
   R = 200 SQ. FT. FOR 500 - 8000 Hz
8. CHECK ACOUSTIC ABSORPTION TREATMENT:

   ☐ NONE OR NRC = 0.65 - 0.74 ☑ NRC = 0.75 - 0.85

THEN, FOR	31 Hz	0.2 R = ______	0.2 R =	40
	63 Hz	0.2 R = ______	0.3 R =	60
	125 Hz	0.3 R = ______	0.5 R =	100
	250 Hz	0.5 R = ______	0.8 R =	160

9. ROOM CONSTANT FOR ALL OCTAVE BANDS, IN SQ. FT.#
   (Repeat appropriate values from Items 7 and 8)

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000
40	60	100	160	200	200	200	200	200

+Add 50% of floor area to Item 4 if floor is carpeted or has drapes or upholstered furniture. Treat this as NRC = 0.65 material.

#Add to all bands any area always open to the outside, ie having 100% absorption.

Form this reminder is given by the second footnote.

d. DA Form 3452-15-R. This Data Form is used to estimate the SPL within the Boiler Room due to each piece of equipment. For this particular sample calculation, referring still to Figure A, interest is confined to noise transmission to the Computer Room (beyond the east wall of the MER) and to the Building Manager's Office (beyond the west wall of the MER). In an actual problem, data would be filled in for the floor and ceiling and all the walls separating the MER from adjoining spaces.

On pages 70 and 71, the two sheets of sample DA Form 3452-15-R are filled in for the 2000 BHP boiler. For the case of boiler noise, the noise source is considered as the front face of the boiler, so all distances are measured from the nearest part of the front face. Hence, the front of the 2000 BHP boiler is approximately 30 ft from the east wall and 25 ft from the center of the Building Manager's Office. The distance corrections for the Item 4 distances are obtained from Table 20 and inserted in the appropriate spaces of Item 6. The SPLs at those distances are then given in Item 7.

On pages 71 and 73, the two sheets of this sample DA Form are filled in for one steam valve, located about 15 ft from the east wall and about 50 ft from the center of the west wall adjoining the Manager's Office.

When a motor and pump are combined, the highest noise levels in each octave band for each of the two items are taken as the 3-ft SPLs for the combined assembly, and the approximate center of the assembly is taken as the "acoustic center". For this sample calculation only the nearest motor-pump assembly, shown shaded in Figure A on page 61, is taken at this time. For this unit, the distance to the center of the east wall is approximately 45 ft and to the Manager's Office wall 10 ft. The sheets of the sample DA Form for the motor-pump are given on pages 74 and 75.

e. DA Form 3452-16-R. This Data Form is used to combine all the SPL components from the various individual pieces of equipment to give the total SPL at each of the walls and surfaces of the room. Because the SPLs differ around the room, a new Data Form must be used for each surface of interest. In the present example, a sample DA Form is given on page 76 for the east wall joining the Computer Room and a second DA Form is given on page 77 for the west wall joining the Manager's Office.

f. DA Forms 3452-17-R and 3452-18-R. These two forms are used together, so they are introduced here together. The first of the two forms involves the selection of the wall or floor-ceiling construction and ultimately yields the SPL in the room on the other side of that structure. The second form then compares that SPL with the desired Noise Criterion and rates the wall according to its ability to meet the criterion.

On page 59 it was stated that 10-in. thick hollow-core concrete block would normally be used for the east and west walls of the Boiler Room. In the sample DA Form 3452-17-R on page 78, this construction is assumed for the wall between the MER and the Computer Room. When all the data are filled in, the SPL values inside the Computer Room are shown in Item 9. These levels will apply for a distance of about one to two wall heights from the wall, i.e. within about 8 to 16 ft of the wall. The SPLs will drop off gradually at greater distances from the wall. On page 79, the sample DA Form 3452-18-R is filled in for the Computer Room. It is seen in Item 6 that the SPL estimate is below the NC-45 criterion in all octave bands. This yields a "preferred" wall design as shown in Item 7. (If all the equipment in the Boiler Room of Figure A were considered, the SPLs in both the Boiler Room and the Computer Room would be a few dB higher than shown, but this wall would still yield a "preferred" design.)

A similar approach is followed for the Building Manager's Office. A sample DA Form 3452-17-R is shown on page 80. Recognizing that the noise levels in this room should be approximately 10 dB lower than in the Computer Room, assume as a "first trial" that the wall to the Boiler Room is made of 10-in. solid-core dense concrete block. The material for this room is then completed on page 81 with DA Form 3452-18-R. In Item 6 on page 81 it is found that the SPLs would exceed an NC-35 condition by only 1 dB in the 250 Hz frequency band. Item 8 then defines this as an "acceptable" wall design for this application. If all the equipment in the Boiler Room were considered, the SPLs would be a few dB higher, and this wall could possibly be found to be "marginal" or "unacceptable" for this design.

For sake of argument, assume here that the wall is "marginal" or "unacceptable". This would raise some questions. Should the wall TL be further increased? Should a double wall or a corridor be placed between the Boiler Room and the office? Should the office be moved and less critical spaces be located here? Should the noise criterion be reconsidered and possibly compromised? Should the Boiler Room equipment be redistributed to achieve quieter conditions at the office?

(text continued on page 82)

DA FORM 3452-15-R, 10 Aug 70 SHEET 1 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT

EQUIPMENT IDENTIFICATION

TYPE BOILER BHP 2000 RPM ____

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. SPL OF EQUIPMENT AT 3-FT DISTANCE, FROM TABLE 5 OF MANUAL OR OTHER SOURCE

92	92	92	89	86	83	80	77	74

2. SPECIAL ADJUSTMENTS, IF ANY, TO ITEM 1 DATA.

   EXPLAIN: ____

3. RESULTING SPL AFTER ADJUSTMENTS

92	92	92	89	86	83	80	77	74

4. DISTANCE FROM EQUIPMENT TO VARIOUS WALLS AND SURFACES OF INTEREST (ALL DISTANCES IN FT).

   NORTH WALL ____ SOUTH WALL ____ EAST WALL 30 WEST WALL ____

   CEILING ____ FLOOR+ ____ (+Assume 3 ft unless different)

   SURFACE "A" (IDENTIFY): MGR'S OFFICE DISTANCE 25

   SURFACE "B" (IDENTIFY): ____ DISTANCE ____

   SURFACE "C" (IDENTIFY): ____ DISTANCE ____

   SURFACE "D" (IDENTIFY): ____ DISTANCE ____

5. ROOM CONSTANT FOR THIS ROOM (FROM ITEM 9 OF DA FORM 3452-14-R.

900	1300	2100	3300	4100	4100	4100	4100	4100

DA FORM 3452-15-R, 10 Aug 70 SHEET 2 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT (CONT.)
(BOILER)

	OCTAVE FREQUENCY BAND IN Hz								
	31	63	125	250	500	1000	2000	4000	8000

6. SPL REDUCTION FOR VARIOUS DISTANCES AND ROOM CONSTANTS, FROM TABLE 20 OR FIGURE 11 (FILL IN SPACES ONLY FOR SURFACES OF INTEREST)

	31	63	125	250	500	1000	2000	4000	8000
NORTH									
SOUTH									
EAST	5	6	7	9	10	10	10	10	10
WEST									
CEIL.									
FLOOR+									
"A"	5	6	7	8	9	9	9	9	9
"B"									
"C"									
"D"									

+Floor value is "0" for all bands, if distance is 3 ft

7. SPL AT SURFACES OF INTEREST FOR THIS PIECE OF EQUIPMENT ONLY (ITEM 7 = ITEM 3 - ITEM 6)

	31	63	125	250	500	1000	2000	4000	8000
NORTH									
SOUTH									
EAST	87	86	85	80	76	73	70	67	64
WEST									
CEIL.									
FLOOR									
"A"	87	86	85	81	77	74	71	68	65
"B"									
"C"									
"D"									

DA FORM 3452-15-R, 10 Aug 70 SHEET 1 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT

EQUIPMENT IDENTIFICATION

TYPE STEAM VALVE HP______ RPM____

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. SPL OF EQUIPMENT AT 3-FT DISTANCE, FROM TABLE 5 OF MANUAL OR OTHER SOURCE

70	70	70	70	75	80	85	90	95

2. SPECIAL ADJUSTMENTS, IF ANY, TO ITEM 1 DATA.

EXPLAIN: ______________________

3. RESULTING SPL AFTER ADJUSTMENTS

70	70	70	70	75	80	85	90	95

4. DISTANCE FROM EQUIPMENT TO VARIOUS WALLS AND SURFACES OF INTEREST (ALL DISTANCES IN FT).

NORTH WALL ________ SOUTH WALL ________ EAST WALL 15 WEST WALL ________

CEILING ________ FLOOR + ________ (+Assume 3 ft unless different)

SURFACE "A" (IDENTIFY): MGR'S OFFICE DISTANCE 50

SURFACE "B" (IDENTIFY): ________ DISTANCE ________

SURFACE "C" (IDENTIFY): ________ DISTANCE ________

SURFACE "D" (IDENTIFY): ________ DISTANCE ________

5. ROOM CONSTANT FOR THIS ROOM (FROM ITEM 9 OF DA FORM 3452-14-R.

900	1300	2100	3300	4100	4100	4100	4100	4100

DA FORM 3452-15-R, 10 Aug 70 SHEET 2 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT (CONT.)
(STEAM VALVE)

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

6. SPL REDUCTION FOR VARIOUS DISTANCES AND ROOM CONSTANTS, FROM TABLE 20 OR FIGURE 11 (FILL IN SPACES ONLY FOR SURFACES OF INTEREST)

	31	63	125	250	500	1000	2000	4000	8000
NORTH									
SOUTH									
EAST	4	5	6	7	8	8	8	8	8
WEST									
CEIL.									
FLOOR+									
"A"	6	7	8	10	11	11	11	11	11
"B"									
"C"									
"D"									

+Floor value is "0" for all bands, if distance is 3 ft

7. SPL AT SURFACES OF INTEREST FOR THIS PIECE OF EQUIPMENT ONLY (ITEM 7 = ITEM 3 - ITEM 6)

	31	63	125	250	500	1000	2000	4000	8000
NORTH									
SOUTH									
EAST	66	65	64	63	67	72	77	82	87
WEST									
CEIL.									
FLOOR									
"A"	64	63	62	60	64	69	74	79	84
"B"									
"C"									
"D"									

DA FORM 3452-15-R, 10 Aug 70 SHEET 1 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT

EQUIPMENT IDENTIFICATION

TYPE MOTOR - PUMP HP 50 RPM 1750

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. SPL OF EQUIPMENT AT 3-FT DISTANCE, FROM TABLE 12 OF MANUAL OR OTHER SOURCE PUMP

86	86	89	91	91	89	86	83	78

2. SPECIAL ADJUSTMENTS, IF ANY, TO ITEM 1 DATA.

EXPLAIN: MOTOR, FROM TABLE 13

82	83	87	91	92	92	91	85	78

3. RESULTING SPL AFTER ADJUSTMENTS ← USE HIGHEST LEVELS IN EACH BAND

86	86	89	91	92	92	91	85	78

4. DISTANCE FROM EQUIPMENT TO VARIOUS WALLS AND SURFACES OF INTEREST (ALL DISTANCES IN FT).

NORTH WALL ________ SOUTH WALL ________ EAST WALL 45 WEST WALL ________

CEILING ________ FLOOR+ ________ (+ Assume 3 ft unless different)

SURFACE "A" (IDENTIFY): MGR'S OFFICE DISTANCE 10

SURFACE "B" (IDENTIFY): ________ DISTANCE ________

SURFACE "C" (IDENTIFY): ________ DISTANCE ________

SURFACE "D" (IDENTIFY): ________ DISTANCE ________

5. ROOM CONSTANT FOR THIS ROOM (FROM ITEM 9 OF DA FORM 3452-14-R).

900	1300	2100	3300	4100	4100	4100	4100	4100

DA FORM 3452-15-R, 10 Aug 70 SHEET 2 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT (CONT.)
(MOTOR - PUMP)

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

6. SPL REDUCTION FOR VARIOUS DISTANCES AND ROOM CONSTANTS, FROM TABLE 20 OR FIGURE 11 (FILL IN SPACES ONLY FOR SURFACES OF INTEREST)

	31	63	125	250	500	1000	2000	4000	8000
NORTH									
SOUTH									
EAST	6	7	8	10	11	11	11	11	11
WEST									
CEIL.									
FLOOR+									
"A"	4	5	6	7	7	7	7	7	7
"B"									
"C"									
"D"									

+Floor value is "0" for all bands, if distance is 3 ft

7. SPL AT SURFACES OF INTEREST FOR THIS PIECE OF EQUIPMENT ONLY (ITEM 7 = ITEM 3 - ITEM 6)

	31	63	125	250	500	1000	2000	4000	8000
NORTH									
SOUTH									
EAST	80	79	81	81	81	81	80	74	67
WEST									
CEIL.									
FLOOR									
"A"	82	81	83	84	85	85	84	78	71
"B"									
"C"									
"D"									

DA FORM 3452-16-R, 10 Aug 70

SUMMATION OF SPLs DUE TO ALL EQUIPMENT
IN MECHANICAL EQUIPMENT ROOM (MER)

MER NO. OR DESIGNATION BOILER ROOM

CHECK WALL OR SURFACE INVOLVED IN THIS SUMMATION

NORTH WALL ☐ SOUTH WALL ☐ EAST WALL ☑ WEST WALL ☐ CEIL-ING ☐ FLOOR ☐

OR OTHER SURFACE DESIGNATION COMPUTER ROOM

IN NUMBERED SPACES BELOW, IDENTIFY EQUIPMENT WHOSE NOISE LEVELS CONTRIBUTE TO TOTAL SPL AT INDICATED WALL OR SURFACE. IN SPL SPACES, INSERT SPL VALUES AT THAT SURFACE DUE TO THAT EQUIPMENT, AS TAKEN FROM ITEM 7 OF DA FORM 3452-15-R.

	OCTAVE FREQUENCY BAND IN Hz								
	31	63	125	250	500	1000	2000	4000	8000
1. BOILER AT 30 FT	87	86	85	80	76	73	70	67	64
2. STEAM VALVE AT 15 FT	66	65	64	63	67	72	77	82	87
3. MOTOR-PUMP AT 45 FT	80	79	81	81	81	81	80	74	67
4.									
5.									

6. TOTAL SPL AT INDICATED WALL OR SURFACES DUE TO ABOVE EQUIPMENT, USING DECIBEL SUMMATION RULES OF TABLE 18. FOR FLOOR, USE HIGHEST READING IN EACH BAND FROM ITEMS 1-5.

88	87	86	84	82	82	82	83	87

DA FORM 3452-16-R, 10 Aug 70

SUMMATION OF SPLs DUE TO ALL EQUIPMENT
IN MECHANICAL EQUIPMENT ROOM (MER)

MER NO. OR DESIGNATION BOILER ROOM

CHECK WALL OR SURFACE INVOLVED IN THIS SUMMATION

NORTH WALL ☐ SOUTH WALL ☐ EAST WALL ☐ WEST WALL ☑ CEIL-ING ☐ FLOOR ☐

OR OTHER SURFACE DESIGNATION MANAGER'S OFFICE

IN NUMBERED SPACES BELOW, IDENTIFY EQUIPMENT WHOSE NOISE LEVELS CONTRIBUTE TO TOTAL SPL AT INDICATED WALL OR SURFACE. IN SPL SPACES, INSERT SPL VALUES AT THAT SURFACE DUE TO THAT EQUIPMENT, AS TAKEN FROM ITEM 7 OF DA FORM 3452-15-R.

	OCTAVE FREQUENCY BAND IN Hz								
	31	63	125	250	500	1000	2000	4000	8000
1. BOILER AT 25 FT	87	86	85	81	77	74	71	68	65
2. STEAM VALVE AT 50 FT	64	63	62	60	64	69	74	79	84
3. MOTOR - PUMP AT 10 FT	82	81	83	84	85	85	84	78	71
4.									
5.									

6. TOTAL SPL AT INDICATED WALL OR SURFACES DUE TO ABOVE EQUIPMENT, USING DECIBEL SUMMATION RULES OF TABLE 18. FOR FLOOR, USE HIGHEST READING IN EACH BAND FROM ITEMS 1-5.

88	87	87	86	86	85	85	82	84

DA FORM 3452-17-R, 10 Aug 70

SOUND TRANSMISSION FROM MER TO ADJOINING ROOM
THROUGH COMMON WALL OR FLOOR-CEILING

SOUND TRANSMITTING ROOM BOILER ROOM SOUND RECEIVING ROOM COMPUTER ROOM

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. AREA S_W OF COMMON TRANSMITTING WALL [✓] OR FLOOR [ ]
50 X 8 = 400 SQ. FT.

2. ROOM CONSTANT R_2 OF REC. RM; ITEM 9 OF DA FORM 3452-14-R

300	450	750	1200	1500	1500	1500	1500	1500

3. RATIO S_W/R_2 (ITEM 1 / ITEM 2)

1.33	0.89	0.53	0.33	0.27	0.27	0.27	0.27	0.27

4. WALL OR FLOOR CORRECTION TERM C FOR ITEM 3 RATIOS, FROM TABLE 32

−2	−1	+1	+2	+3	+3	+3	+3	+3

5. PROPOSED WALL OR FLOOR CONSTRUCTION 10" HOLLOW-CORE CONCRETE BLOCK

6. "TL" OF PROPOSED WALL OR FLOOR. SEE TABLES 21-31 FOR WALL TLs; SEE TABLES 34 - 38 FOR FLOOR-CEILING TLs.

30	32	34	36	38	43	50	56	61

7. "NR" OF PROPOSED WALL OR FLOOR. NR = TL + C
ITEM 7 = ITEM 6 + ITEM 4

28	31	35	38	41	46	53	59	64

8. SPL ON MER SIDE OF WALL OR FLOOR, FROM ITEM 6 OF DA FORM 3452-16-R FOR ALL EQUIPMENT CONTRIBUTIONS OR APPROPRIATE LINE OF ITEM 7 OF DA FORM 3452-15-R IF FOR ONLY ONE PIECE OF EQUIPMENT

88	87	86	84	82	82	82	83	87

9. SPL IN RECEIVING ROOM DUE TO MER NOISE TRANSMITTED THROUGH WALL OR FLOOR OF ITEM 5 ABOVE.
$SPL_{REC.\ RM.} = SPL_{MER} - NR$. ITEM 9 = ITEM 8 - ITEM 7

60	56	51	46	41	36	29	24	23

DA FORM 3452-18-R, 10 Aug 70

COMPARISON OF ROOM SPL WITH NOISE CRITERION

SOUND RECEIVING ROOM COMPUTER ROOM

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. APPLICABLE ROOM CATEGORY NO. 5 FROM TABLE 2 OF MANUAL
2. SUGGESTED NOISE CRITERION FOR ROOM: NC- 45
3. SPL VALUES CORRESPONDING TO NC VALUE OF ITEM 2; FROM TABLE 1 OF MANUAL

	67	60	54	49	46	44	43	42

4. PROPOSED WALL OR FLOOR CONSTRUCTION BETWEEN MER AND REC. RM; FROM ITEM 5 OF DA FORM 3452-17-R. 10" HOLLOW-CORE CONCRETE BLOCK
5. SPL IN RECEIVING ROOM FOR ITEM 4 WALL; FROM ITEM 9 OF DA FORM 3452-17-R.

60	56	51	46	41	36	29	24	23

6. COMPARISON OF ITEM 5 WITH ITEM 3 ABOVE. IF ITEM 5 SPL EXCEEDS ITEM 3 SPL IN ANY FREQUENCY BAND, INSERT THE AMOUNT OF THAT EXCESS IN THE APPROPRIATE SPACE BELOW

—	—	—	—	—	—	—	—	—

7. IF THERE IS NO NOISE EXCESS IN ANY BAND, WALL OR FLOOR DESIGN IS PREFERRED. CHECK HERE ☑
8. IF NOISE EXCESS IS NOT GREATER THAN THE FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS ACCEPTABLE. CHECK HERE ☐

4	4	4	3	2	2	2	2	2

9. IF NOISE EXCESS IS WITHIN FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS MARGINAL. CHECK HERE ☐

5-7	5-7	5-7	4-6	3-5	3-5	3-5	3-5	3-5

10. IF NOISE EXCESS IS GREATER THAN ITEM 9 VALUES IN ANY BAND, WALL OR FLOOR IS UNACCEPTABLE. CHECK HERE ☐

DA FORM 3452-17-R, 10 Aug 70

SOUND TRANSMISSION FROM MER TO ADJOINING ROOM THROUGH COMMON WALL OR FLOOR-CEILING

SOUND TRANSMITTING ROOM BOILER ROOM

SOUND RECEIVING ROOM MANAGER'S OFFICE

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. AREA S_W OF COMMON TRANSMITTING WALL ☑ OR FLOOR ☐

   15 X 8 = 120 SQ. FT.

2. ROOM CONSTANT R_2 OF REC. RM; ITEM 9 OF DA FORM 3452-14-R

31	63	125	250	500	1000	2000	4000	8000
40	60	100	160	200	200	200	200	200

3. RATIO S_W/R_2 (ITEM 1 / ITEM 2)

31	63	125	250	500	1000	2000	4000	8000
3.0	2.0	1.2	0.75	0.6	0.6	0.6	0.6	0.6

4. WALL OR FLOOR CORRECTION TERM C FOR ITEM 3 RATIOS, FROM TABLE 32

31	63	125	250	500	1000	2000	4000	8000
-5	-4	-2	0	+1	+1	+1	+1	+1

5. PROPOSED WALL OR FLOOR CONSTRUCTION 10" SOLID DENSE CONCRETE BLOCK

6. "TL" OF PROPOSED WALL OR FLOOR. SEE TABLES 21-31 FOR WALL TLs; SEE TABLES 34 - 38 FOR FLOOR-CEILING TLs.

31	63	125	250	500	1000	2000	4000	8000
34	35	37	40	45	52	58	63	68

7. "NR" OF PROPOSED WALL OR FLOOR. NR = TL + C
   ITEM 7 = ITEM 6 + ITEM 4

31	63	125	250	500	1000	2000	4000	8000
29	31	35	40	46	53	59	64	69

8. SPL ON MER SIDE OF WALL OR FLOOR, FROM ITEM 6 OF DA FORM 3452-16-R FOR ALL EQUIPMENT CONTRIBUTIONS OR APPROPRIATE LINE OF ITEM 7 OF DA FORM 3452-15-R IF FOR ONLY ONE PIECE OF EQUIPMENT

31	63	125	250	500	1000	2000	4000	8000
88	87	87	86	86	85	85	82	84

9. SPL IN RECEIVING ROOM DUE TO MER NOISE TRANSMITTED THROUGH WALL OR FLOOR OF ITEM 5 ABOVE.
   $SPL_{REC.\ RM.} = SPL_{MER} - NR$. ITEM 9 = ITEM 8 - ITEM 7

31	63	125	250	500	1000	2000	4000	8000
59	56	52	46	40	32	26	18	15

DA FORM 3452-18-R, 10 Aug 70

COMPARISON OF ROOM SPL WITH NOISE CRITERION

SOUND RECEIVING ROOM MANAGER'S OFFICE

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. APPLICABLE ROOM CATEGORY NO. 3 FROM TABLE 2 OF MANUAL
2. SUGGESTED NOISE CRITERION FOR ROOM: NC- 35
3. SPL VALUES CORRESPONDING TO NC VALUE OF ITEM 2; FROM TABLE 1 OF MANUAL

	60	52	45	40	36	34	33	32

4. PROPOSED WALL OR FLOOR CONSTRUCTION BETWEEN MER AND REC. RM; FROM ITEM 5 OF DA FORM 3452-17-R 10" SOLID DENSE CONCRETE BLOCK
5. SPL IN RECEIVING ROOM FOR ITEM 4 WALL; FROM ITEM 9 OF DA FORM 3452-17-R

59	56	52	46	40	32	26	18	15

6. COMPARISON OF ITEM 5 WITH ITEM 3 ABOVE. IF ITEM 5 SPL EXCEEDS ITEM 3 SPL IN ANY FREQUENCY BAND, INSERT THE AMOUNT OF THAT EXCESS IN THE APPROPRIATE SPACE BELOW

—	—	0	1	0	—	—	—	—

7. IF THERE IS NO NOISE EXCESS IN ANY BAND, WALL OR FLOOR DESIGN IS PREFERRED. CHECK HERE ☐
8. IF NOISE EXCESS IS NOT GREATER THAN THE FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS ACCEPTABLE. CHECK HERE ☑

4	4	4	3	2	2	2	2	2

9. IF NOISE EXCESS IS WITHIN FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS MARGINAL. CHECK HERE ☐

5-7	5-7	5-7	4-6	3-5	3-5	3-5	3-5	3-5

10. IF NOISE EXCESS IS GREATER THAN ITEM 9 VALUES IN ANY BAND, WALL OR FLOOR IS UNACCEPTABLE. CHECK HERE ☐

Should quieter equipment be required by imposing a maximum noise level specification? These types of questions are asked and must be answered in facing each critical noise control design problem. These questions will be considered again when this example is pursued later in the text.

g. DA Form 3452-19-R. Now, apart from the example for a moment, suppose a compressor manufacturer has submitted sound power level ("PWL") data for a compressor to be considered for a building. Suppose his PWL values are as follows for the octave frequency bands, expressed in decibels re 10^{-13} watt (a formerly used power reference):

105	103	104	105	109	112	118	115	104

Since the currently used U.S. and International standards refer to 10^{-12} watt reference power, the above values should be reduced 10 dB in order to express them in decibels re 10^{-12} watt:

95	93	94	95	99	102	108	105	94

Using these values and following the procedures given in DA Form 3452-19-R it is possible to estimate the approximate 3-ft SPLs for one of these units. The sample form is filled in on page 83 . Item 7 shows the estimated SPLs at the normal 3-ft distance (6 ft from the assumed acoustic center of the compressor assembly, in this case). A note of caution regarding data offered by the manufacturer, especially if the noise levels appear surprisingly low when compared with other similar equipment: (1) are these "guaranteed" values, (2) do they apply at full-load operation, (3) would the manufacturer (if given the order) accept complete responsibility and cost for installing the equipment that, under full load, would meet his quoted values, and (4) would he submit this guarantee in writing? If the manufacturer's values are "guaranteed" and considered reliable, they may be used in the noise analysis procedure, assuming that the other non-acoustic conditions are satisfied in the agreement. The reader should be cautioned against setting up an entire design based on low noise readings offered by one manufacturer, only to find later that manufacturer withdraws from the final competition or that the finally successful bidder cannot meet the low noise levels claimed by the other supplier.

h. DA Form 3452-20-R. The last form included in this manual relates to the escape of noise from an MER to the outside through ventilation openings. To illustrate the use of the form, suppose that the SPLs at the north wall of the Boiler Room of Figure A on page 61 are as follows:

DA FORM 3452-19-R, 10 Aug 70

ESTIMATED SPL AT 3-FT DISTANCE INDOORS WHEN SOURCE PWL IS KNOWN

EQUIPMENT IDENTIFICATION

TYPE CENTRIFUGAL COMPRESSOR HP 2000 RPM 3600

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. PWL FOR EQUIPMENT IN DB RE 10^{-12} WATT. IF PWL IS REFERRED TO 10^{-13} WATT, SUBTRACT 10 DB FROM ALL VALUES.

95	93	94	95	99	102	108	105	94

2. APPROXIMATE OVERALL DIMENSIONS OF EQUIPMENT, IN FEET. IGNORE ANY PORTION OBVIOUSLY NOT PRODUCING OR RADIATING NOISE.

   LENGTH 8 WIDTH 5 HEIGHT 6

3. ADD THE THREE DIMENSIONS OF ITEM 2; DIVIDE THE SUM BY 6. THE RESULT IS APPROXIMATELY THE "RADIUS" OF THE EQUIPMENT.

   SUM 19 DIVIDED BY 6 = 3+ FT.

4. ADD 3 FT TO THE ITEM 3 VALUE. THIS GIVES THE DISTANCE FROM THE ASSUMED "ACOUSTIC CENTER" OF THE UNIT, WHICH IS APPROXIMATELY 3 FT FROM THE NEAREST PART OF THE UNIT.

   ITEM 3 3 + 3 = 6 FT.

5. ROOM CONSTANT OF MECHANICAL EQUIPMENT ROOM, FROM ITEM 9 OF DA FORM 3452-14-R ASSUMED FOR THIS EXAMPLE

1000	1500	2000	4000	5000	5000	5000	5000	5000

6. DETERMINE "RELATIVE SPL" FROM FIG. 11 OF MANUAL FOR THE DISTANCE DIMENSION OF ITEM 4 ABOVE, FOR EACH OF THE ROOM CONSTANT VALUES OF ITEM 5 ABOVE. INSERT "REL SPL" AND PROPER SIGN (+ OR -) IN SPACES BELOW.

-12	-12	-13	-14	-15	-15	-15	-15	-15

7. APPROXIMATE SPL AT 3-FT DISTANCE. SPL = PWL + REL SPL. ITEM 7 = ITEM 1 + ITEM 6 (CAUTION: KEEP CORRECT SIGNS!) THIS SPL AT THE NORMALIZED 3-FT DISTANCE MAY BE INSERTED INTO ITEM 1 OF DA FORM 3452-15-R AND THIS EQUIPMENT GIVEN THE SAME TREATMENT AS ALL OTHER INDOOR EQUIPMENT IN THE ANALYSIS PROCEDURE.

83	81	81	81	84	87	93	90	79

91	90	89	88	87	86	86	86	90

These noise levels may escape through the 100 sq ft louvered opening along the north wall and might be disturbing to hotel occupants across the street. The sample Data Form on page 85 shows the calculations of the sound power level (PWL) of the noise escaping through the louvered opening. This noise escape will be pursued later.

i. PPA Data Forms. Some of the thirteen data forms contained in the Power Plant Acoustics Manual may be of use with the present manual. Those forms are identified by the Department of the Army publication designations

DA Form 3452-1 through 3452-13

The last four DA Forms of that series are most likely to be called upon occasionally for use with this manual. Some of the wording in those forms may not be exactly appropriate to this manual but the intent of the forms and the calculations will be fairly obvious.

DA Form 3452-10 (Sheets 1 and 2) is entitled "Hearing Preservation Routines for Broad-Band Noise", and DA Form 3452-11 (Sheets 1 and 2) is entitled "Hearing Preservation Routines for Narrow-Band Noise". MER noise may exceed "safe" full-time noise exposure conditions for many MER areas, and both the designer and user should take this into account in providing "safe" operator work areas or control rooms. For more details, refer to the PPA Manual.

DA Form 3452-12 is entitled "Criterion SPL for Critical Neighbor", and DA Form 3452-13 is entitled "Criterion PWL for Critical Neighbor". These forms are used to evaluate the possible impact of outdoor mechanical equipment noise on nearby neighbors. The use of these forms is illustrated in a later portion of the manual.

4-07. NOISE CONTROL TREATMENTS. In most building situations, noise control may be provided by application of the following types of treatments and techniques:

DA FORM 3452-20-R, 10 Aug 70

NOISE ESCAPE THROUGH OPENINGS IN SOURCE ROOM

ROOM IDENTIFICATION BOILER ROOM

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. SPL AT OPENING

91	90	89	88	87	86	86	86	90

2. AREA OF NOISE ESCAPE OPENING: 100 SQ. FT

3. "AREA FACTOR" FROM TABLE 39 FOR ITEM 2 AREA; SAME VALUE FOR ALL FREQUENCY BANDS.

10	10	10	10	10	10	10	10	10

4. PWL OF NOISE AT OPENING (IN DB RE 10^{-12} WATT). ITEM 4= ITEM 1 + ITEM 3

101	100	99	98	97	96	96	96	100

5. ATTENUATION INSERTED IN PATH TO OUTSIDE (MUFFLER LINED DUCT, LINED BEND, ETC.---FROM MUFFLER MFGR, ASHRAE GUIDE, PPA MANUAL, ETC.)

6. PWL OF ESCAPING NOISE (IN DB RE 10^{-12} WATT). ITEM 6 = ITEM 4 - ITEM 5

101	100	99	98	97	96	96	96	100

(1) Use of adequate wall and floor-ceiling constructions to contain the noise and limit its transmission into adjoining areas.

(2) Use of acoustic absorption material in either or both the sound transmitting room and the sound receiving room in order to absorb some of the sound energy that "bounces" around the room. Quantitative data and procedures for incorporating sound absorption materials are included in the Tables and DA Forms.

(3) Use of transmission loss data in order to select various types of construction materials for the design of noise enclosures.

(4) Use of "layout" modifications in an attempt to (a) redistribute noise sources in a more favorable arrangement, (b) bring together noisy areas in one part of a building and quist areas in a different part of the building in order to minimize their reaction on one another, and (c) use less-critical "buffer zones" to separate noisy and quiet areas.

(5) Use of vibration isolation mounts for the support of mechanical or vibrating equipment. Details of such mounts are given in Section V.

(6) Use of mufflers to control noise transmission through air passageways. This is presented in considerable detail on pages 54-64 of the Power Plant Acoustics Manual and is not repeated here.

(7) Use of duct lining treatments to control noise transmission through ducted connections. This is presented briefly on pages 64-65 of the PPA Manual, and detailed material on this subject can be found in the ASHRAE Guide [2].

(8) Use of specifications to limit the noise output of equipment for use in the building; this is suggested and discussed briefly on pages 26-28 of this manual.

(9) Use of the basic elements of acoustics in order to (a) work intelligently with SPL and PWL data for many types of electrical and mechanical noise sources, (b) combine noise sources, (c) know the effects of distance (both indoors and outdoors), (d) appreciate

the significance of noise criteria, and (e) be able to manipulate acoustic data in a meaningful and rational way.

With these noise control procedures at hand, it should be possible to work out most typical problems associated with the noise of mechanical and electrical equipment in the MER. As stated earlier, very unusual or critical problems may require more profound analyses and treatments.

4-08. EXAMPLE, CONTINUED. In Paragraph 4-06, a Boiler Room example was described and sample DA Forms were introduced. A few simple parts of a total MER noise design were carried out in order to illustrate the use of the Data Forms.

In order to resolve each problem posed by the example, the Boiler Room is now re-examined in detail and the information contained in the manual (with some assistance from the PPA Manual) is brought to bear on this one typical complete MER example.

a. Boiler Room Modifications. In the earlier approach to the problem, the Boiler Room layout was shown in Figure A on page 61. In the pursuit of the earlier example, it was suggested that with all equipment in operation a 10-in. thick solid-core dense concrete block wall might fail to achieve the desired NC-35 criterion in the Building Manager's Office. At that point (page 69), several questions were asked but not answered.

One important noise control design treatment is "layout". In the floor plan of Figure A the NC-35 Manager's Office was located immediately adjoining the MER. Of course, this location can be handled with the use of a double wall or a corridor, but each of these would be space-consuming and costly. Where possible it would be desirable to locate a less critical "buffer zone" between the quiet and noisy areas. A suggested Boiler Room re-arrangement is shown in Figure B on page 88 . Compared to the original layout, several changes are made. Obviously, there are unlimited arrangements possible, but the one shown here attempts to locate noise sources and noise receivers to best advantage relative to one another. The reasons for the changes are listed below.

(1) In the original layout, the Building Manager's Office needed the greatest amount of noise reduction. In the new layout the

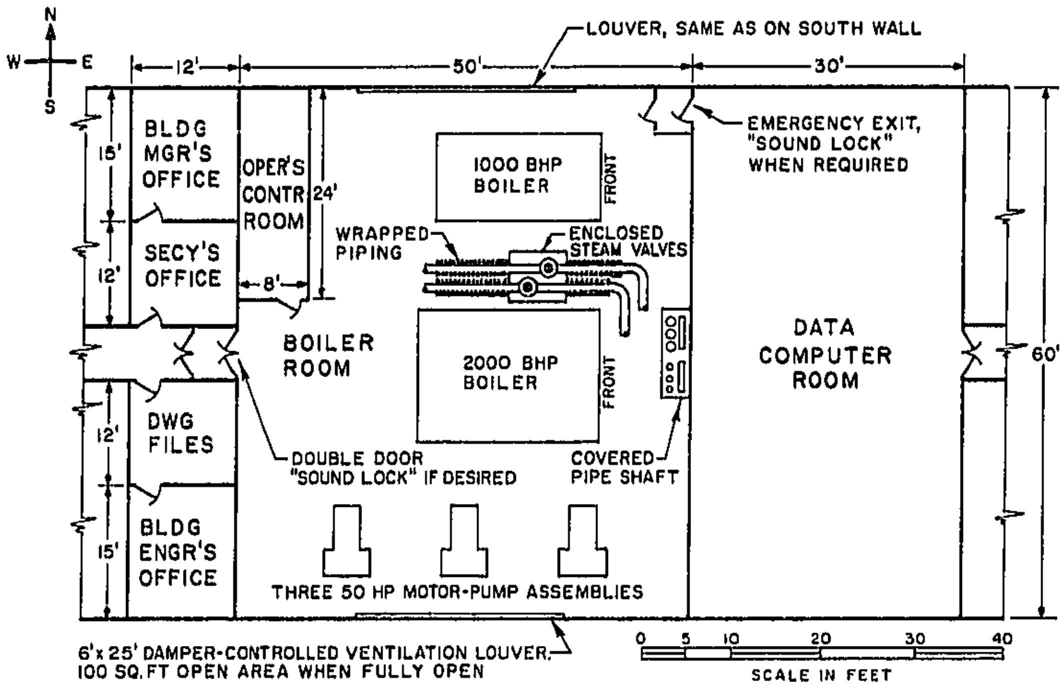


FIG. B REARRANGED LAYOUT OF BOILER ROOM FOR IMPROVED NOISE DISTRIBUTION

Manager's Office is moved and the Control Room is placed as a "buffer" between the MER and the Manager's Office. The Control Room dimensions are changed from 10 ft x 20 ft to 8 ft x 24 ft so that the 24 ft length will not only cover the Manager's Office but also a large portion of the Secretary's Office. The Control Room serves as a "double wall" for the two offices, and the remaining short length of the single wall at the Secretary's Office would now provide a more favorable value of "C" in Table 32 (the wall area S_w common to the MER and the Secretary's Office is now small, so that less sound energy can pass through).

(2) The motor-pump assemblies were crowded together in Figure A to use minimum floor area. This concentration of noise sources would have provided an especially high noise level into any office located immediately under these pumps on the floor below. That specific case was not worked out in the previous example, but it is a fact nevertheless. Since the motor-pump units are quite noisy sources in the mid-frequency bands that frequently control the wall and floor designs, it is desirable to separate these sources as much as possible. An alternate location for the pumps would be along the north wall instead of along the south wall of the MER. For the north location, however, the pumps would be closer to the ventilation opening nearest the hotel. It will be seen later that noise escape from that ventilation opening is a small potential problem, but at least it is kept small by locating the pumps as far away from the ventilation opening as possible.

(3) In the new layout, the Computer Room would be subject to higher noise levels than with the previous layout. The pumps, and the front surfaces of the boilers are now closer to the Computer Room, and the full 60-ft wall length is now exposed to the MER whereas the Control Room formerly "protected" 10 ft of that wall.

(4) An emergency exit from the MER was formerly provided through the Control Room into the Computer Room. Since the Control Room served as a "buffer", the TL of the door would not have been particularly crucial. Now, a better door will be required. A special "acoustic door" (Table 24) or a double door arrangement forming a "sound lock" would be required for a more-or-less critical neighboring area. A suggested door for this wall will be determined in the details that follow. Note that the door has been placed at a large distance from the noisiest sources (the motors and pumps). If safety regulations require that the door be placed closer to the pumps, this could be handled with a still better door.

(5) The Building Engineer's Office is now subject to slightly higher noise levels because it is closer to the pumps.

(6) In order to illustrate in this example some part of all the noise control treatments available, suppose that several motor manufacturers are willing to guarantee motors that will meet the PWL values listed by IEEE [8] for 1800-RPM, 50-HP motors of the "totally-enclosed fan-cooled" type, which are as follows for the octave frequency bands (PWL in dB re 10^{-12} watt):

--	--	81	88	94	94	90	81	74

At the peak bands, these levels are 5 dB lower than the levels given in Table 13 for this motor.

(7) In the earlier preliminary analysis of the Boiler Room, it was found (but not discussed) that steam valve noise would exceed an NC-25 as heard inside the nearby hotel rooms with windows open. In addition, steam valve noise inside the MER exceeds "safe" levels for long-time daily exposures of personnel, so it would be desirable to reduce those levels.

As a noise control treatment for steam valve noise, a box-like enclosure can be built around the valves, and the nearest 20 ft of pipe on either side of each valve can be given an acoustic pipe wrapping (better than the normal thermal wrapping). The box enclosure can be made of any suitable impervious material that will withstand the temperature. The enclosure material should have a surface weight of not less than about 5 lb/sq ft and the interior of the box should be lined with 2-in. thick acoustic absorption material. The door to the enclosure should be of similar material and should be closed and sealed against a gasketed frame. The noise reduction provided by such a box would be about 5 dB in the low frequency region, 10 dB in the mid frequency region and about 15-20 dB in the high frequency region.

The steam piping also radiates the valve noise, and to reduce this radiated noise, it is usually necessary to supplement the regular thermal insulation with an "acoustic wrapping". An adequate acoustic wrapping would probably consist of 4-in. total thickness (including thermal wrapping in this case) of a suitable fibrous thermal insulation material (glass fiber or mineral wool or equal) of minimum density 3-4 lb/cu ft which is then covered with an impervious skin having a surface weight of at least 1 lb/sq ft, or even greater if possible. Aluminum, steel or lead-loaded wrappings, or a sprayed or troweled application of dense plaster, magnesia or cement could be used for the impervious skin. This wrapping should extend from the valve inside the box enclosure for a distance of at least 20 ft either side of the box. A good seal should be made where the covered piping enters the holes in the enclosure. This pipe wrapping would be compatible with the box enclosure of the valves, and the complete treatment would yield the noise reduction attributed above to the enclosure. This steam valve and pipe treatment is illustrated in Figure B and is assumed for the detailed analysis that follows.

(8) MER noise levels could be transmitted down the pipe shaft shown in Figures A and B and could possibly be radiated into quiet spaces bordering the pipe shaft at the lower floors. In a thorough study this pipe shaft noise could be subjected to a complete analysis, but it will be less expensive and more positive to merely require that the top of the pipe shaft (at the MER floor line or higher) be capped-off with a form-fitting cover that provides adequate clearance holes for all the required piping. Caulking or fibrous stuffing can be used to close up the final air cracks around the pipes. A cast concrete cover of 2 in. to 4 in. thickness would be ideal, but heavy sheet metal or thick plywood could be used to produce an interim cover. If that cover is later found to be inadequate, it could be used as part of the form for pouring a concrete cover.

With the above acoustic treatments assumed for the Figure B arrangement of the Boiler Room and the adjoining spaces, the noise control design may now be started anew. All the applicable conditions named earlier on pages 59-63 are still assumed.

b. Room Constant. The Room Constant is now calculated for all rooms involved in the analysis, using DA Form 3452-14-R. The acoustic absorption characteristics are unchanged for the rooms that have already been calculated, so those values still apply:

for Boiler Room see page 65,
for Computer Room see page 66 ,
for Building Manager's Office and
Building Engineer's Office see page 67 .

On the following pages, Room Constants are calculated for the new Control Room (page 93), the Secretary's Office (page 94), and a large typical office or conference room (page 95), assumed located under the middle of the MER. A carpeted and furnished office is assumed, so the first footnote of the Data Form is appropriate and an additional 150 sq ft of absorption is added to Item 4. It is anticipated that a Type 4 floor-ceiling may be involved, and this requires a plaster ceiling as a sound barrier. Acoustic tiles are then assumed to be attached directly to the underside of the plaster. All of this leads typically to an NRC ("noise reduction coefficient") in the 0.65 - 0.74 group, whereas the air space above the suspended acoustic ceiling in the other rooms would normally give rise to NRCs in the 0.75 to 0.85 range.

c. Equipment SPLs. Next, the SPLs are estimated for the various pieces of equipment for the various walls and surfaces of the Boiler Room that adjoin critical areas. The south wall and the ceiling are not involved in the problem, so SPLs are not required for these surfaces. DA Form 3452-15-R is used. Because some MER walls border more than one critical room, the Data Form is adapted to meet the specific layout needs.

The SPL distribution within the MER is given on pages 96-99 for the two Boilers. On pages 100-101 the SPLs are given for one steam valve, using the box enclosure and the pipe wrapping discussed earlier on pages 90-91. The noise reduction for the enclosure and wrapping are estimated and included in Item 2. On pages 103-104 the SPLs are derived for one motor-pump assembly. Recall that for this example the motor PWL was assumed to be specified by several motor manufacturers, as given on page 90 . The 3-ft SPLs are then calculated from the PWL using DA Form 3452-19-R. SPLs for a motor-pump unit are calculated for distances of 12,25 and 37 ft (the distances from the three units to the walls of the Engineer's Office and the Computer Room), 40 ft

(text continued on page 105)

DA FORM 3452-14-R, 10 Aug 70

ROOM CONSTANT OF SOURCE ROOM OR RECEIVER ROOM

ROOM NO. OR DESIGNATION CONTROL ROOM

1. AVERAGE ROOM DIMENSIONS (IN FT.)
   LENGTH 24 WIDTH 8 HEIGHT 8
2. VOLUME OF ROOM 1540 CU. FT.
3. TOTAL INTERIOR SURFACE AREA OF ROOM 896 SQ. FT.
4. AREA OF PLANNED ACOUSTIC TREATMENT+ 192 SQ. FT.
5. PERCENT AREA COVERED BY ACOUSTIC TREATMENT 21 %
   (100 x Item 4/Item 3)
6. "ROOM LABEL" FOR ITEM 5 FROM PART A OF TABLE 19
   AVERAGE
7. FOR ITEMS 2 AND 6, ROOM CONSTANT FROM FIGURE 12
   R = 150 SQ. FT. FOR 500 - 8000 Hz
8. CHECK ACOUSTIC ABSORPTION TREATMENT:

	☐ NONE OR NRC = 0.65 - 0.74	☑ NRC = 0.75 - 0.85
THEN, FOR 31 Hz	0.2 R =	0.2 R = 30
63 Hz	0.2 R =	0.3 R = 45
125 Hz	0.3 R =	0.5 R = 75
250 Hz	0.5 R =	0.8 R = 120

9. ROOM CONSTANT FOR ALL OCTAVE BANDS, IN SQ. FT.#
   (Repeat appropriate values from Items 7 and 8)

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000
30	45	75	120	150	150	150	150	150

+Add 50% of floor area to Item 4 if floor is carpeted or has drapes or upholstered furniture. Treat this as NRC = 0.65 material.

#Add to all bands any area always open to the outside, i.e. having 100% absorption.

DA FORM 3452-14-R, 10 Aug 70

ROOM CONSTANT OF SOURCE ROOM OR RECEIVER ROOM

ROOM NO. OR DESIGNATION SECRETARY'S OFFICE
(SIMILAR TO FILE ROOM)

1. AVERAGE ROOM DIMENSIONS (IN FT.)
   LENGTH 12 WIDTH 12 HEIGHT 8
2. VOLUME OF ROOM 1152 CU. FT.
3. TOTAL INTERIOR SURFACE AREA OF ROOM 672 SQ. FT.
4. AREA OF PLANNED ACOUSTIC TREATMENT+ 144 SQ. FT.
5. PERCENT AREA COVERED BY ACOUSTIC TREATMENT 21 %
   (100 x Item 4/Item 3)
6. "ROOM LABEL" FOR ITEM 5 FROM PART A OF TABLE 19
   AVERAGE
7. FOR ITEMS 2 AND 6, ROOM CONSTANT FROM FIGURE 12
   R = 120 SQ. FT. FOR 500 - 8000 Hz
8. CHECK ACOUSTIC ABSORPTION TREATMENT:

	☐ NONE OR NRC = 0.65 - 0.74	☑ NRC = 0.75 - 0.85
THEN, FOR 31 Hz	0.2 R =	0.2 R = 24
63 Hz	0.2 R =	0.3 R = 36
125 Hz	0.3 R =	0.5 R = 60
250 Hz	0.5 R =	0.8 R = 96

9. ROOM CONSTANT FOR ALL OCTAVE BANDS, IN SQ. FT.#
   (Repeat appropriate values from Items 7 and 8)

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000
24	36	60	96	120	120	120	120	120

+Add 50% of floor area to Item 4 if floor is carpeted or has drapes or upholstered furniture. Treat this as NRC = 0.65 material.

#Add to all bands any area always open to the outside, i.e. having 100% absorption.

DA FORM 3452-14-R, 10 Aug 70

ROOM CONSTANT OF SOURCE ROOM OR RECEIVER ROOM

ROOM NO. OR DESIGNATION TYPICAL OFFICE OR CONFERENCE ROOM BENEATH BOILER ROOM

1. AVERAGE ROOM DIMENSIONS (IN FT.)
   LENGTH 20 WIDTH 15 HEIGHT 8
2. VOLUME OF ROOM 2400 CU. FT.
3. TOTAL INTERIOR SURFACE AREA OF ROOM 1160 SQ. FT.
4. AREA OF PLANNED ACOUSTIC TREATMENT+ 300+150+ = 450 SQ. FT.
5. PERCENT AREA COVERED BY ACOUSTIC TREATMENT 39 %
   (100 x Item 4/Item 3)
6. "ROOM LABEL" FOR ITEM 5 FROM PART A OF TABLE 19
   MEDIUM-DEAD TO DEAD
7. FOR ITEMS 2 AND 6, ROOM CONSTANT FROM FIGURE 12
   R = 500 SQ. FT. FOR 500 - 8000 Hz
8. CHECK ACOUSTIC ABSORPTION TREATMENT:

   ☑ NONE OR NRC = 0.65 - 0.74 ☐ NRC = 0.75 - 0.85

		NRC = 0.65 - 0.74	NRC = 0.75 - 0.85
THEN, FOR	31 Hz	0.2 R = 100	0.2 R =
	63 Hz	0.2 R = 100	0.3 R =
	125 Hz	0.3 R = 150	0.5 R =
	250 Hz	0.5 R = 250	0.8 R =

9. ROOM CONSTANT FOR ALL OCTAVE BANDS, IN SQ. FT.#
   (Repeat appropriate values from Items 7 and 8)

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000
100	100	150	250	500	500	500	500	500

+Add 50% of floor area to Item 4 if floor is carpeted or has drapes or upholstered furniture. Treat this as NRC = 0.65 material.

#Add to all bands any area always open to the outside, i.e. having 100% absorption.

DA FORM 3452-15-R, 10 Aug 70 SHEET 1 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT

EQUIPMENT IDENTIFICATION

TYPE BOILER BHP 1000 RPM ____

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. SPL OF EQUIPMENT AT 3-FT DISTANCE, FROM TABLE 5 OF MANUAL OR OTHER SOURCE

92	92	92	89	86	83	80	77	74

2. SPECIAL ADJUSTMENTS, IF ANY, TO ITEM 1 DATA.

EXPLAIN: ____

3. RESULTING SPL AFTER ADJUSTMENTS

92	92	92	89	86	83	80	77	74

4. DISTANCE FROM EQUIPMENT TO VARIOUS WALLS AND SURFACES OF INTEREST (ALL DISTANCES IN FT).

NORTH WALL 5 SOUTH WALL ____ EAST WALL 10 WEST WALL ____

CEILING ____ FLOOR + ____ (+Assume 3 ft unless different)

SURFACE "A" (IDENTIFY): CONTROL ROOM DISTANCE 32

SURFACE "B" (IDENTIFY): ENGR'S OFFICE DISTANCE 55

SURFACE "C" (IDENTIFY): ____ DISTANCE ____

SURFACE "D" (IDENTIFY): ____ DISTANCE ____

5. ROOM CONSTANT FOR THIS ROOM (FROM ITEM 9 OF DA FORM 3452-14-R).

900	1300	2100	3300	4100	4100	4100	4100	4100

DA FORM 3452-15-R, 10 Aug 70

SHEET 2 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT (CONT.)

	OCTAVE FREQUENCY BAND IN Hz								
	31	63	125	250	500	1000	2000	4000	8000

6. SPL REDUCTION FOR VARIOUS DISTANCES AND ROOM CONSTANTS, FROM TABLE 20 OR FIGURE 11 (FILL IN SPACES ONLY FOR SURFACES OF INTEREST)

	31	63	125	250	500	1000	2000	4000	8000
NORTH	2	2	3	4	4	4	4	4	4
SOUTH									
EAST	4	5	6	7	8	8	8	8	8
WEST									
CEIL.									
FLOOR+	0	0	0	0	0	0	0	0	0
"A"	5	6	8	9	10	10	10	10	10
"B"	6	7	8	11	12	12	12	12	12
"C"									
"D"									

+Floor value is "0" for all bands, if distance is 3 ft

7. SPL AT SURFACES OF INTEREST FOR THIS PIECE OF EQUIPMENT ONLY (ITEM 7 = ITEM 3 - ITEM 6)

	31	63	125	250	500	1000	2000	4000	8000
NORTH	90	90	89	85	82	79	76	73	70
SOUTH									
EAST	88	87	86	82	78	75	72	69	66
WEST									
CEIL.									
FLOOR	92	92	92	89	86	83	80	77	74
"A"	87	86	84	80	76	73	70	67	64
"B"	86	85	84	78	74	71	68	65	62
"C"									
"D"									

DA FORM 3452-15-R, 10 Aug 70 SHEET 1 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT

EQUIPMENT IDENTIFICATION

TYPE BOILER BHP 2000 RPM ____

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. SPL OF EQUIPMENT AT 3-FT DISTANCE, FROM TABLE 5 OF MANUAL OR OTHER SOURCE

92	92	92	89	86	83	80	77	74

2. SPECIAL ADJUSTMENTS, IF ANY, TO ITEM 1 DATA.

   EXPLAIN: ____

3. RESULTING SPL AFTER ADJUSTMENTS

92	92	92	89	86	83	80	77	74

4. DISTANCE FROM EQUIPMENT TO VARIOUS WALLS AND SURFACES OF INTEREST (ALL DISTANCES IN FT).

   NORTH WALL 25 SOUTH WALL ____ EAST WALL 10 WEST WALL ____

   CEILING ____ FLOOR+ 3 (+Assume 3 ft unless different)

   SURFACE "A" (IDENTIFY): CONTROL ROOM DISTANCE 32

   SURFACE "B" (IDENTIFY): ENGR's OFFICE DISTANCE 40

   SURFACE "C" (IDENTIFY): ____ DISTANCE ____

   SURFACE "D" (IDENTIFY): ____ DISTANCE ____

5. ROOM CONSTANT FOR THIS ROOM (FROM ITEM 9 OF DA FORM 3452-14-R.

900	1300	2100	3300	4100	4100	4100	4100	4100

DA FORM 3452-15-R, 10 Aug 70 SHEET 2 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT (CONT.)

	OCTAVE FREQUENCY BAND IN Hz								
	31	63	125	250	500	1000	2000	4000	8000

6. SPL REDUCTION FOR VARIOUS DISTANCES AND ROOM CONSTANTS, FROM TABLE 20 OR FIGURE 11 (FILL IN SPACES ONLY FOR SURFACES OF INTEREST)

	31	63	125	250	500	1000	2000	4000	8000
NORTH	5	6	7	8	9	9	9	9	9
SOUTH									
EAST	4	5	6	7	8	8	8	8	8
WEST									
CEIL.									
FLOOR+	0	0	0	0	0	0	0	0	0
"A"	5	6	8	9	10	10	10	10	10
"B"	6	7	8	10	11	11	11	11	11
"C"									
"D"									

+Floor value is "O" for all bands, if distance is 3 ft

7. SPL AT SURFACES OF INTEREST FOR THIS PIECE OF EQUIPMENT ONLY (ITEM 7 = ITEM 3 - ITEM 6)

	31	63	125	250	500	1000	2000	4000	8000
NORTH	87	86	85	81	77	74	71	68	65
SOUTH									
EAST	88	87	86	82	78	75	72	69	66
WEST									
CEIL.									
FLOOR	92	92	92	89	86	83	80	77	74
"A"	87	86	84	80	76	73	70	67	64
"B"	86	85	84	79	75	72	69	66	63
"C"									
"D"									

DA FORM 3452-15-R, 10 Aug 70 SHEET 1 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT

EQUIPMENT IDENTIFICATION

TYPE STEAM VALVE HP ______ RPM ______

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. SPL OF EQUIPMENT AT 3-FT DISTANCE, FROM TABLE 5 OF MANUAL OR OTHER SOURCE

70	70	70	70	75	80	85	90	95

2. SPECIAL ADJUSTMENTS, IF ANY, TO ITEM 1 DATA.
EXPLAIN: BOX ENCLOSURE PLUS PIPE WRAPPING

-5	-5	-6	-10	-12	-14	-16	-18	-20

3. RESULTING SPL AFTER ADJUSTMENTS

65	65	64	60	63	66	69	72	75

4. DISTANCE FROM EQUIPMENT TO VARIOUS WALLS AND SURFACES OF INTEREST (ALL DISTANCES IN FT).

NORTH WALL 20 SOUTH WALL ______ EAST WALL 15 WEST WALL ______

CEILING ______ FLOOR+ 5 (+Assume 3 ft unless different)

SURFACE "A" (IDENTIFY): CONTROL ROOM DISTANCE 25

SURFACE "B" (IDENTIFY): ENGR'S OFFICE DISTANCE 45

SURFACE "C" (IDENTIFY): ______ DISTANCE ______

SURFACE "D" (IDENTIFY): ______ DISTANCE ______

5. ROOM CONSTANT FOR THIS ROOM (FROM ITEM 9 OF DA FORM 3452-14-R

900	1300	2100	3300	4100	4100	4100	4100	4100

DA FORM 3452-15-R,. 10 Aug 70 SHEET 2 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT (CONT.)

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

6. SPL REDUCTION FOR VARIOUS DISTANCES AND ROOM CONSTANTS, FROM TABLE 20 OR FIGURE 11 (FILL IN SPACES ONLY FOR SURFACES OF INTEREST)

	31	63	125	250	500	1000	2000	4000	8000
NORTH	5	6	7	8	9	9	9	9	9
SOUTH									
EAST	4	5	6	7	8	8	8	8	8
WEST									
CEIL.									
FLOOR+	2	2	3	4	4	4	4	4	4
"A"	5	6	7	8	9	9	9	9	9
"B"	6	7	8	10	11	11	11	11	11
"C"									
"D"									

+Floor value is "0" for all bands, if distance is 3 ft

7. SPL AT SURFACES OF INTEREST FOR THIS PIECE OF EQUIPMENT ONLY (ITEM 7 = ITEM 3 - ITEM 6)

	31	63	125	250	500	1000	2000	4000	8000
NORTH	60	59	57	52	54	57	60	63	66
SOUTH									
EAST	61	60	58	53	55	58	61	64	67
WEST									
CEIL.									
FLOOR	63	63	61	56	59	62	65	68	71
"A"	60	59	57	52	54	57	60	63	66
"B"	59	58	56	50	52	55	58	61	64
"C"									
"D"									

DA FORM 3452-19-R, 10 Aug 70

ESTIMATED SPL AT 3-FT DISTANCE INDOORS WHEN SOURCE PWL IS KNOWN

EQUIPMENT IDENTIFICATION

TYPE ELECTRIC MOTOR HP 50 RPM 1750

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. PWL FOR EQUIPMENT IN DB RE 10^{-12} WATT. IF PWL IS REFERRED TO 10^{-13} WATT, SUBTRACT 10 DB FROM ALL VALUES.

FROM MANUFACTURER'S SPECIFICATION

—	—	81	88	94	94	90	81	74

2. APPROXIMATE OVERALL DIMENSIONS OF EQUIPMENT, IN FEET. IGNORE ANY PORTION OBVIOUSLY NOT PRODUCING OR RADIATING NOISE.

   LENGTH 2 WIDTH 2 HEIGHT 2

3. ADD THE THREE DIMENSIONS OF ITEM 2; DIVIDE THE SUM BY 6. THE RESULT IS APPROXIMATELY THE "RADIUS" OF THE EQUIPMENT.

   SUM 6 DIVIDED BY 6 = 1 FT.

4. ADD 3 FT TO THE ITEM 3 VALUE. THIS GIVES THE DISTANCE FROM THE ASSUMED "ACOUSTIC CENTER" OF THE UNIT, WHICH IS APPROXIMATELY 3 FT FROM THE NEAREST PART OF THE UNIT.

   ITEM 3 1 + 3 = 4 FT.

5. ROOM CONSTANT OF MECHANICAL EQUIPMENT ROOM, FROM ITEM 9 OF DA FORM 3452-14-R

900	1300	2100	3300	4100	4100	4100	4100	4100

6. DETERMINE "RELATIVE SPL" FROM FIG. 11 OF MANUAL FOR THE DISTANCE DIMENSION OF ITEM 4 ABOVE, FOR EACH OF THE ROOM CONSTANT VALUES OF ITEM 5 ABOVE. INSERT "REL SPL" AND PROPER SIGN (+ OR -) IN SPACES BELOW.

-10	-10	-11	-11	-12	-12	-12	-12	-12

7. APPROXIMATE SPL AT 3-FT DISTANCE. SPL = PWL + REL SPL. ITEM 7 = ITEM 1 + ITEM 6 (CAUTION: KEEP CORRECT SIGNS!) THIS SPL AT THE NORMALIZED 3-FT DISTANCE MAY BE INSERTED INTO ITEM 1 OF DA FORM 3452-15-R AND THIS EQUIPMENT GIVEN THE SAME TREATMENT AS ALL OTHER INDOOR EQUIPMENT IN THE ANALYSIS PROCEDURE.

—	—	70	77	82	82	78	69	62

DA FORM 3452-15-R, 10 Aug 70 SHEET 1 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT

EQUIPMENT IDENTIFICATION

TYPE MOTOR - PUMP HP 50 RPM 1750

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. SPL OF EQUIPMENT AT 3-FT DISTANCE, FROM TABLE 12 OF MANUAL OR OTHER SOURCE

86	86	89	91	91	89	86	83	78

2. SPECIAL ADJUSTMENTS, IF ANY, TO ITEM 1 DATA.

   EXPLAIN: MOTOR, BY MFGR. SPEC.

—	—	70	77	82	82	78	69	62

3. RESULTING SPL AFTER ADJUSTMENTS HIGHEST SPL IN EACH FREQUENCY BAND

86	86	89	91	91	89	86	83	78

4. DISTANCE FROM EQUIPMENT TO VARIOUS WALLS AND SURFACES OF INTEREST (ALL DISTANCES IN FT).

   NORTH WALL 50 SOUTH WALL ______ EAST WALL SEE "B" "C" "D" WEST WALL SEE "B" "C" "D"

   CEILING ______ FLOOR+ 3 (+Assume 3 ft unless different)

   SURFACE "A" (IDENTIFY): CONTROL ROOM DISTANCE 40 (AVG.)

   SURFACE "B" (IDENTIFY): NEAR PUMP DISTANCE 12

   SURFACE "C" (IDENTIFY): MIDDLE PUMP DISTANCE 25

   SURFACE "D" (IDENTIFY): FAR PUMP DISTANCE 37

5. ROOM CONSTANT FOR THIS ROOM (FROM ITEM 9 OF DA FORM 3452-14-R).

900	1300	2100	3300	4100	4100	4100	4100	4100

DA FORM 3452-15-R, 10 Aug 70 SHEET 2 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT (CONT.)

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

6. SPL REDUCTION FOR VARIOUS DISTANCES AND ROOM CONSTANTS, FROM TABLE 20 OR FIGURE 11 (FILL IN SPACES ONLY FOR SURFACES OF INTEREST)

	31	63	125	250	500	1000	2000	4000	8000
NORTH	6	7	8	10	11	11	11	11	11
SOUTH									
EAST									
WEST									
CEIL.									
FLOOR+	0	0	0	0	0	0	0	0	0
"A"	6	7	8	10	11	11	11	11	11
"B"	4	5	6	7	7	7	7	7	7
"C"	5	6	7	8	9	9	9	9	9
"D"	6	7	8	10	11	11	11	11	11

+Floor value is "0" for all bands, if distance is 3 ft

7. SPL AT SURFACES OF INTEREST FOR THIS PIECE OF EQUIPMENT ONLY (ITEM 7 = ITEM 3 - ITEM 6)

	31	63	125	250	500	1000	2000	4000	8000	
NORTH	80	79	81	81	80	78	75	72	67	
SOUTH										
EAST										
WEST										
CEIL.										
FLOOR	86	86	89	91	91	89	86	83	78	
"A"	80	79	81	81	80	78	75	72	67	
"B"	82	81	83	84	84	82	79	76	71	12 FT
"C"	81	80	82	83	82	80	77	74	69	25 FT
"D"	80	79	81	81	80	78	75	72	67	37 FT

(the approximate average distance from all three units to the Control Room) and 50 ft (the distance of all three units to the north wall of the MER). These various SPLs will be combined in the next paragraph.

d. SPL Summations. The SPL contributions of the various noise sources at the various walls and surfaces of the MER are combined in DA Form 3452-16-R. The sample Data Forms on pages 107-111 give the summations at the north wall (for noise escape through the ventilation opening to the hotel across the street), at the east wall adjoining the Computer Room, at the west wall adjoining the Control Room, at the west wall adjoining the Engineer's Office, and at the floor, which is taken to be above a critical office on the floor below. This material is fairly straightforward, although a special comment should be made about applying the summation procedure to the floor (for the office below the MER). For each of the walls, the individual contributions of Items 1-5 are added together by "decibel addition" (see Table 18) to obtain the total SPL given in Item 6. This summation procedure is modified, however, for the floor position: instead of adding the components, use the highest SPL reading found in each octave band in the entries of Items 1-5. Recall that the floor readings are usually the 3-ft SPLs which are themselves the highest levels in the room and these values apply quite locally around each piece of equipment. Thus, it is not necessary to add these contributions. When the highest octave band reading from Items 1-5 is used for Item 6, this assures that the ultimate floor-ceiling design will protect all equipment locations in the MER.

e. Wall Selections. The final steps in the analysis are carried out by filling in the blanks of DA Forms 3452-17-R and 3452-18-R Until the user becomes proficient with the procedure, there may be a few "trial and error" attempts in which a given wall design is tried, only to find that the resulting room SPLs will not meet the noise criterion SPLs set up for the room. Note that Items 7-10 on DA Form 3452-18-R define the degree of acceptability or unacceptability of a given wall.

The Data Forms for the selection of the MER walls adjoining the Computer Room, the Operator's Control Room, and the Building Engineer's Office are given on pages 112-117. Recall from the earlier conditions that a 10-in. hollow-core concrete block wall would normally be used to enclose the MER and that ¼ in. glass would normally be used to enclose the Control Room. The Data Forms on pages 112-113 show that the 10-in. hollow-core dense concrete block wall would rate "preferred" for the wall between the MER and the Computer Room, while the Data Forms on pages 116-117 show that a 10-in. thick solid-core dense concrete block wall would be rated "preferred" for the wall between the MER and the Engineer's Office. The ¼ in. glass wall between the MER and the Control Room (pages 114-115) will meet a "preferred" rating for providing a quiet working area free of any risk of hearing damage and will yield a "speech interference level" (PSIL) of 61 dB (see Table 3 for voice levels and distances required for reliable speech communication in this noise level environment).

The File Room is sufficiently similar to the Engineer's Office in Noise Criterion, dimensions and acoustic treatment, that the wall requirement can be considered equal to that of the Engineer's Office without a detailed calculation. Thus, the 10-in. solid-core wall would be considered "preferred".

A feature of the Boiler Room re-arrangement of Figure B (page 88) is the use of the Control Room as a "buffer zone" between the Boiler Room and the Manager's Office. The noise levels transmitted into the Manager's Office can be calculated from DA Forms 3452-17-R and 3452-18-R by letting the Control Room now be the sound transmitting room and the Manager's Office be the sound receiving room. The SPLs in the Control Room are taken from Item 9 on page 114. The calculations are shown on pages 118-119. A 10-in. solid-core dense concrete block wall is suggested in order to be consistent with the wall of the Secretary's Office, the File Room and the Engineer's Office. This wall is found to be "preferred". Actually a lighter weight wall would be satisfactory but it would represent a change from the remainder of this west wall of the MER and the change might be more troublesome than keeping the entire wall alike. Also, it would be desirable to keep the heavy wall, so that the noise levels in the Manager's Office would not rise noticeably every time the Control Room door is opened and Boiler Room noise enters.

In the new Boiler Room layout, the Control Room is intentionally allowed to cover a part of the wall to the Secretary's Office, thus leaving a reduced area of wall of that office exposed to Boiler Room noise. This gives a favorable value of "C" in Table 32. This situation is calculated on pages 120-121, where it is found that the 10-in. thick solid-core dense concrete block wall will be "preferred" The MER SPLs incident on this exposed portion of wall (Item 8 on page

(text continued on page 122)

DA FORM 3452-16-R, 10 Aug 70

SUMMATION OF SPLs DUE TO ALL EQUIPMENT
IN MECHANICAL EQUIPMENT ROOM (MER)

MER NO. OR DESIGNATION BOILER ROOM

CHECK WALL OR SURFACE INVOLVED IN THIS SUMMATION

NORTH WALL [✓] SOUTH WALL [ ] EAST WALL [ ] WEST WALL [ ] CEILING [ ] FLOOR [ ]

OR OTHER SURFACE DESIGNATION ______

IN NUMBERED SPACES BELOW, IDENTIFY EQUIPMENT WHOSE NOISE LEVELS CONTRIBUTE TO TOTAL SPL AT INDICATED WALL OR SURFACE. IN SPL SPACES, INSERT SPL VALUES AT THAT SURFACE DUE TO THAT EQUIPMENT, AS TAKEN FROM ITEM 7 OF DA FORM 3452-15-R.

	OCTAVE FREQUENCY BAND IN Hz									
	31	63	125	250	500	1000	2000	4000	8000	
1. 1000 BHP BOILER AT 5 FT	90	90	89	85	82	79	76	73	70	
2. 2000 BHP BOILER AT 25 FT	87	86	85	81	77	74	71	68	65	
3. 2 ENCLOSED STEAM VALVES AT 20 FT	63	62	60	55	57	60	63	66	69	3 dB ABOVE SPL OF 1 VALVE
4. 3 MOTOR-PUMPS AT 50 FT	85	84	86	86	85	83	80	77	72	5 dB ABOVE SPL OF 1 UNIT
5.										

6. TOTAL SPL AT INDICATED WALL OR SURFACES DUE TO ABOVE EQUIPMENT, USING DECIBEL SUMMATION RULES OF TABLE 18. FOR FLOOR, USE HIGHEST READING IN EACH BAND FROM ITEMS 1-5.

93	92	92	89	87	84	81	79	76

DA FORM 3452-16-R, 10 Aug 70

SUMMATION OF SPLs DUE TO ALL EQUIPMENT
IN MECHANICAL EQUIPMENT ROOM (MER)

MER NO. OR DESIGNATION BOILER ROOM

CHECK WALL OR SURFACE INVOLVED IN THIS SUMMATION

NORTH WALL ☐ SOUTH WALL ☐ EAST WALL ☑ WEST WALL ☐ CEILING ☐ FLOOR ☐

OR OTHER SURFACE DESIGNATION COMPUTER ROOM

IN NUMBERED SPACES BELOW, IDENTIFY EQUIPMENT WHOSE NOISE LEVELS CONTRIBUTE TO TOTAL SPL AT INDICATED WALL OR SURFACE. IN SPL SPACES, INSERT SPL VALUES AT THAT SURFACE DUE TO THAT EQUIPMENT, AS TAKEN FROM ITEM 7 OF DA FORM 3452-15-R .

	OCTAVE FREQUENCY BAND IN Hz								
	31	63	125	250	500	1000	2000	4000	8000
1. 1000 BHP BOILER AT 10 FT	88	87	86	82	78	75	72	69	66
2. 2000 BHP BOILER AT 10 FT	88	87	86	82	78	75	72	69	66
3. 2 ENCLOSED STEAM VALVES AT 15 FT	64	63	61	56	58	61	64	67	70
4. 3 MOTOR-PUMPS (12, 25, 37 FT DISTANCES)	86	85	87	88	87	85	82	79	74
5.									

6. TOTAL SPL AT INDICATED WALL OR SURFACES DUE TO ABOVE EQUIPMENT, USING DECIBEL SUMMATION RULES OF TABLE 18. FOR FLOOR, USE HIGHEST READING IN EACH BAND FROM ITEMS 1-5.

92	91	91	90	88	86	83	80	76

DA FORM 3452-16-R, 10 Aug 70

SUMMATION OF SPLs DUE TO ALL EQUIPMENT
IN MECHANICAL EQUIPMENT ROOM (MER)

MER NO. OR DESIGNATION BOILER ROOM

CHECK WALL OR SURFACE INVOLVED IN THIS SUMMATION

NORTH WALL ☐ SOUTH WALL ☐ EAST WALL ☐ WEST WALL ☑ CEILING ☐ FLOOR ☐

OR OTHER SURFACE DESIGNATION CONTROL ROOM

IN NUMBERED SPACES BELOW, IDENTIFY EQUIPMENT WHOSE NOISE LEVELS CONTRIBUTE TO TOTAL SPL AT INDICATED WALL OR SURFACE. IN SPL SPACES, INSERT SPL VALUES AT THAT SURFACE DUE TO THAT EQUIPMENT, AS TAKEN FROM ITEM 7 OF DA FORM 3452-15-R

	OCTAVE FREQUENCY BAND IN Hz								
	31	63	125	250	500	1000	2000	4000	8000
1. 1000 BHP BOILER AT 32 FT	87	86	84	80	76	73	70	67	64
2. 2000 BHP BOILER AT 32 FT	87	86	84	80	76	73	70	67	64
3. 2 ENCLOSED STEAM VALVES AT 25 FT	63	62	60	55	57	60	63	66	69
4. 3 MOTOR-PUMPS AT 40 FT	85	84	86	86	85	83	80	77	72
5.									

6. TOTAL SPL AT INDICATED WALL OR SURFACES DUE TO ABOVE EQUIPMENT, USING DECIBEL SUMMATION RULES OF TABLE 18. FOR FLOOR, USE HIGHEST READING IN EACH BAND FROM ITEMS 1-5.

91	90	89	88	86	84	81	78	75

DA FORM 3452-16-R, 10 Aug 70

SUMMATION OF SPLs DUE TO ALL EQUIPMENT
IN MECHANICAL EQUIPMENT ROOM (MER)

MER NO. OR DESIGNATION BOILER ROOM

CHECK WALL OR SURFACE INVOLVED IN THIS SUMMATION

NORTH WALL ☐ SOUTH WALL ☐ EAST WALL ☐ WEST WALL ☑ CEILING ☐ FLOOR ☐

OR OTHER SURFACE DESIGNATION ENGINEER'S OFFICE

IN NUMBERED SPACES BELOW, IDENTIFY EQUIPMENT WHOSE NOISE LEVELS CONTRIBUTE TO TOTAL SPL AT INDICATED WALL OR SURFACE. IN SPL SPACES, INSERT SPL VALUES AT THAT SURFACE DUE TO THAT EQUIPMENT, AS TAKEN FROM ITEM 7 OF DA FORM 3452-15-R.

	OCTAVE FREQUENCY BAND IN Hz								
	31	63	125	250	500	1000	2000	4000	8000
1. 1000 BHP BOILER AT 55 FT	86	85	84	78	74	71	68	65	62
2. 2000 BHP BOILER AT 40 FT	86	85	84	79	75	72	69	66	63
3. 2 ENCLOSED STEAM VALVES AT 45 FT	62	61	59	53	55	58	61	64	67
4. 3 MOTOR-PUMPS (12, 25, 37 FT DISTANCES)	86	85	87	88	87	85	82	79	74
5.									

6. TOTAL SPL AT INDICATED WALL OR SURFACES DUE TO ABOVE EQUIPMENT, USING DECIBEL SUMMATION RULES OF TABLE 18. FOR FLOOR, USE HIGHEST READING IN EACH BAND FROM ITEMS 1-5.

91	90	90	90	87	85	82	79	75

DA FORM 3452-16-R, 10 Aug 70

SUMMATION OF SPLs DUE TO ALL EQUIPMENT
IN MECHANICAL EQUIPMENT ROOM (MER)

MER NO. OR DESIGNATION BOILER ROOM

CHECK WALL OR SURFACE INVOLVED IN THIS SUMMATION

NORTH WALL ☐ SOUTH WALL ☐ EAST WALL ☐ WEST WALL ☐ CEILING ☐ FLOOR ☑

OR OTHER SURFACE DESIGNATION ____________

IN NUMBERED SPACES BELOW, IDENTIFY EQUIPMENT WHOSE NOISE LEVELS CONTRIBUTE TO TOTAL SPL AT INDICATED WALL OR SURFACE. IN SPL SPACES, INSERT SPL VALUES AT THAT SURFACE DUE TO THAT EQUIPMENT, AS TAKEN FROM ITEM 7 OF DA FORM 3452-15-R.

	OCTAVE FREQUENCY BAND IN Hz								
	31	63	125	250	500	1000	2000	4000	8000
1. 1000 BHP BOILER AT 3 FT	92	92	92	89	86	83	80	77	74
2. 2000 BHP BOILER AT 3 FT	92	92	92	89	86	83	80	77	74
3. 2 ENCLOSED STEAM VALVES AT 5 FT	66	66	64	59	62	65	68	71	74
4. 1 MOTOR-PUMP AT 3 FT	86	86	89	91	91	89	86	83	78
5.									

6. TOTAL SPL AT INDICATED WALL OR SURFACES DUE TO ABOVE EQUIPMENT, USING DECIBEL SUMMATION RULES OF TABLE 18. FOR FLOOR, USE HIGHEST READING IN EACH BAND FROM ~~ITEMS 1-5.~~

92	92	92	91	91	89	86	83	78

DA FORM 3452-17-R, 10 Aug 70

SOUND TRANSMISSION FROM MER TO ADJOINING ROOM
THROUGH COMMON WALL OR FLOOR-CEILING

SOUND TRANSMITTING ROOM: BOILER ROOM — SOUND RECEIVING ROOM: COMPUTER ROOM

	OCTAVE FREQUENCY BAND IN Hz								
	31	63	125	250	500	1000	2000	4000	8000
1. AREA S_W OF COMMON TRANSMITTING WALL [✓] OR FLOOR [ ]: 60 X 8 = 480 SQ. FT.									
2. ROOM CONSTANT R_2 OF REC. RM; ITEM 9 OF DA FORM 3452-14-R.	300	450	750	1200	1500	1500	1500	1500	1500
3. RATIO S_W/R_2 (ITEM 1 / ITEM 2)	1.6	1.06	0.64	0.40	0.32	0.32	0.32	0.32	0.32
4. WALL OR FLOOR CORRECTION TERM C FOR ITEM 3 RATIOS, FROM TABLE 32	−3	−1	0	+2	+2	+2	+2	+2	+2
5. PROPOSED WALL OR FLOOR CONSTRUCTION: 10" HOLLOW-CORE DENSE CONCRETE BLOCK									
6. "TL" OF PROPOSED WALL OR FLOOR. SEE TABLES 21-31 FOR WALL TLs; SEE TABLES 34 - 38 FOR FLOOR-CEILING TLs.	30	32	34	36	38	43	50	56	61
7. "NR" OF PROPOSED WALL OR FLOOR. NR = TL + C. ITEM 7 = ITEM 6 + ITEM 4	27	31	34	38	40	45	52	58	63
8. SPL ON MER SIDE OF WALL OR FLOOR, FROM ITEM 6 OF DA FORM 3452-16-R FOR ALL EQUIPMENT CONTRIBUTIONS OR APPROPRIATE LINE OF ITEM 7 OF DA FORM 3452-15-R IF FOR ONLY ONE PIECE OF EQUIPMENT	92	91	91	90	88	86	83	80	76
9. SPL IN RECEIVING ROOM DUE TO MER NOISE TRANSMITTED THROUGH WALL OR FLOOR OF ITEM 5 ABOVE. $SPL_{REC.\ RM.} = SPL_{MER} - NR$. ITEM 9 = ITEM 8 - ITEM 7	65	60	57	52	48	41	31	22	13

DA FORM 3452-18-R, 10 Aug 70

COMPARISON OF ROOM SPL WITH NOISE CRITERION

SOUND RECEIVING ROOM COMPUTER ROOM

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. APPLICABLE ROOM CATEGORY NO. 5 FROM TABLE 2 OF MANUAL
2. SUGGESTED NOISE CRITERION FOR ROOM: NC- 45
3. SPL VALUES CORRESPONDING TO NC VALUE OF ITEM 2; FROM TABLE 1 OF MANUAL

	67	60	54	49	46	44	43	42

4. PROPOSED WALL OR FLOOR CONSTRUCTION BETWEEN MER AND REC. RM; FROM ITEM 5 OF DA FORM 3452-17-R 10" HOLLOW-CORE DENSE CONCRETE BLOCK
5. SPL IN RECEIVING ROOM FOR ITEM 4 WALL; FROM ITEM 9 OF DA FORM 3452-17-R

65	60	57	52	48	41	31	22	13

6. COMPARISON OF ITEM 5 WITH ITEM 3 ABOVE. IF ITEM 5 SPL EXCEEDS ITEM 3 SPL IN ANY FREQUENCY BAND, INSERT THE AMOUNT OF THAT EXCESS IN THE APPROPRIATE SPACE BELOW

—	—	—	—	—	—	—	—	—

7. IF THERE IS NO NOISE EXCESS IN ANY BAND, WALL OR FLOOR DESIGN IS PREFERRED. CHECK HERE ☑
8. IF NOISE EXCESS IS NOT GREATER THAN THE FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS ACCEPTABLE. CHECK HERE ☐

4	4	4	3	2	2	2	2	2

9. IF NOISE EXCESS IS WITHIN FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS MARGINAL. CHECK HERE ☐

5-7	5-7	5-7	4-6	3-5	3-5	3-5	3-5	3-5

10. IF NOISE EXCESS IS GREATER THAN ITEM 9 VALUES IN ANY BAND, WALL OR FLOOR IS UNACCEPTABLE. CHECK HERE ☐

DA FORM 3452-17-R, 10 Aug 70

SOUND TRANSMISSION FROM MER TO ADJOINING ROOM THROUGH COMMON WALL OR FLOOR-CEILING

SOUND TRANSMITTING ROOM BOILER ROOM   SOUND RECEIVING ROOM CONTROL ROOM

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. AREA S_W OF COMMON TRANSMITTING WALL [✓] OR FLOOR [ ]
32 x 8 = 256 SQ. FT.

2. ROOM CONSTANT R_2 OF REC. RM; ITEM 9 OF DA FORM 3452-14-R

30	45	75	120	150	150	150	150	150

3. RATIO S_W/R_2 (ITEM 1 / ITEM 2)

8.5	5.7	3.4	2.1	1.7	1.7	1.7	1.7	1.7

4. WALL OR FLOOR CORRECTION TERM C FOR ITEM 3 RATIOS, FROM TABLE 32

-9	-8	-6	-4	-3	-3	-3	-3	-3

5. PROPOSED WALL OR FLOOR CONSTRUCTION 1/4" GLASS

6. "TL" OF PROPOSED WALL OR FLOOR. SEE TABLES 21-31 FOR WALL TLs; SEE TABLES 34 - 38 FOR FLOOR-CEILING TLs.

5	11	17	23	25	26	27	28	30

7. "NR" OF PROPOSED WALL OR FLOOR. NR = TL + C
ITEM 7 = ITEM 6 + ITEM 4   # CANNOT BE LESS THAN "0"

0#	3	11	19	22	23	24	25	27

8. SPL ON MER SIDE OF WALL OR FLOOR, FROM ITEM 6 OF DA FORM 3452-16-R FOR ALL EQUIPMENT CONTRIBUTIONS OR APPROPRIATE LINE OF ITEM 7 OF DA FORM 3452-15-R IF FOR ONLY ONE PIECE OF EQUIPMENT

91	90	89	88	86	84	81	78	75

9. SPL IN RECEIVING ROOM DUE TO MER NOISE TRANSMITTED THROUGH WALL OR FLOOR OF ITEM 5 ABOVE.
$SPL_{REC.\ RM.} = SPL_{MER} - NR$. ITEM 9 = ITEM 8 - ITEM 7

91	87	78	69	64	61	57	53	48

PSIL = 61 dB

DA FORM 3452-18-R, 10 Aug 70

COMPARISON OF ROOM SPL WITH NOISE CRITERION

SOUND RECEIVING ROOM CONTROL ROOM

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

~~1. APPLICABLE ROOM CATEGORY NO. ___ FROM TABLE 2 OF MANUAL~~

10 DB BELOW NARROW-BAND HEARING CONSERVATION

~~2. SUGGESTED NOISE CRITERION FOR ROOM: NC-~~

LEVELS PREFERRED. COL. 3 TABLE 2 OF

~~3. SPL VALUES CORRESPONDING TO NC VALUE OF ITEM 2; FROM TABLE 1 OF MANUAL~~

PPA MANUAL

	—	—	77	70	70	70	70	70

4. PROPOSED WALL OR FLOOR CONSTRUCTION BETWEEN MER AND REC. RM; FROM ITEM 5 OF DA FORM 3452-17-R 1/4" GLASS

5. SPL IN RECEIVING ROOM FOR ITEM 4 WALL; FROM ITEM 9 OF DA FORM 3452-17-R

91	87	78	69	64	61	57	53	48

6. COMPARISON OF ITEM 5 WITH ITEM 3 ABOVE. IF ITEM 5 SPL EXCEEDS ITEM 3 SPL IN ANY FREQUENCY BAND, INSERT THE AMOUNT OF THAT EXCESS IN THE APPROPRIATE SPACE BELOW

—	—	—	—	—	—	—	—	—

7. IF THERE IS NO NOISE EXCESS IN ANY BAND, WALL OR FLOOR DESIGN IS PREFERRED. CHECK HERE ☑

8. IF NOISE EXCESS IS NOT GREATER THAN THE FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS ACCEPTABLE. CHECK HERE ☐

4	4	4	3	2	2	2	2	2

9. IF NOISE EXCESS IS WITHIN FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS MARGINAL. CHECK HERE ☐

5-7	5-7	5-7	4-6	3-5	3-5	3-5	3-5	3-5

10. IF NOISE EXCESS IS GREATER THAN ITEM 9 VALUES IN ANY BAND, WALL OR FLOOR IS UNACCEPTABLE. CHECK HERE ☐

DA FORM 3452-17-R, 10 Aug 70

SOUND TRANSMISSION FROM MER TO ADJOINING ROOM
THROUGH COMMON WALL OR FLOOR-CEILING

SOUND TRANSMITTING ROOM: BOILER ROOM

SOUND RECEIVING ROOM: ENGINEER'S OFFICE

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. AREA S_W OF COMMON TRANSMITTING WALL [✓] OR FLOOR [ ]
15 x 8 = 120 SQ. FT.

2. ROOM CONSTANT R_2 OF REC. RM; ITEM 9 OF DA FORM 3452-14-R

40	60	100	160	200	200	200	200	200

3. RATIO S_W / R_2 (ITEM 1 / ITEM 2)

3.0	2.0	1.2	0.75	0.6	0.6	0.6	0.6	0.6

4. WALL OR FLOOR CORRECTION TERM C FOR ITEM 3 RATIOS, FROM TABLE 32

-5	-4	-2	0	+1	+1	+1	+1	+1

5. PROPOSED WALL OR FLOOR CONSTRUCTION 10" SOLID DENSE CONCRETE BLOCK

6. "TL" OF PROPOSED WALL OR FLOOR. SEE TABLES 21-31 FOR WALL TLs; SEE TABLES 34 - 38 FOR FLOOR-CEILING TLs.

34	35	37	40	45	52	58	63	68

7. "NR" OF PROPOSED WALL OR FLOOR. NR = TL + C
ITEM 7 = ITEM 6 + ITEM 4

29	31	35	40	46	53	59	64	69

8. SPL ON MER SIDE OF WALL OR FLOOR, FROM ITEM 6 OF DA FORM 3452-16-R FOR ALL EQUIPMENT CONTRIBUTIONS OR APPROPRIATE LINE OF ITEM 7 OF DA FORM 3452-15-R IF FOR ONLY ONE PIECE OF EQUIPMENT

91	90	90	90	87	85	82	79	75

9. SPL IN RECEIVING ROOM DUE TO MER NOISE TRANSMITTED THROUGH WALL OR FLOOR OF ITEM 5 ABOVE.
$SPL_{REC. RM.} = SPL_{MER} - NR$. ITEM 9 = ITEM 8 - ITEM 7

62	59	55	50	41	32	23	15	6

DA FORM 3452-18-R, 10 Aug 70

COMPARISON OF ROOM SPL WITH NOISE CRITERION

SOUND RECEIVING ROOM ENGINEER'S OFFICE

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. APPLICABLE ROOM CATEGORY NO. 3-4 FROM TABLE 2 OF MANUAL
2. SUGGESTED NOISE CRITERION FOR ROOM: NC- 40
3. SPL VALUES CORRESPONDING TO NC VALUE OF ITEM 2; FROM TABLE 1 OF MANUAL

	64	56	50	45	41	39	38	37

4. PROPOSED WALL OR FLOOR CONSTRUCTION BETWEEN MER AND REC. RM; FROM ITEM 5 OF DA FORM 3452-17-R 10" SOLID DENSE CONCRETE BLOCK
5. SPL IN RECEIVING ROOM FOR ITEM 4 WALL; FROM ITEM 9 OF DA FORM 3452-17-R

62	59	55	50	41	32	23	15	6

6. COMPARISON OF ITEM 5 WITH ITEM 3 ABOVE. IF ITEM 5 SPL EXCEEDS ITEM 3 SPL IN ANY FREQUENCY BAND, INSERT THE AMOUNT OF THAT EXCESS IN THE APPROPRIATE SPACE BELOW

—	—	—	0	—	—	—	—	—

7. IF THERE IS NO NOISE EXCESS IN ANY BAND, WALL OR FLOOR DESIGN IS PREFERRED. CHECK HERE ✓
8. IF NOISE EXCESS IS NOT GREATER THAN THE FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS ACCEPTABLE. CHECK HERE

4	4	4	3	2	2	2	2	2

9. IF NOISE EXCESS IS WITHIN FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS MARGINAL. CHECK HERE

5-7	5-7	5-7	4-6	3-5	3-5	3-5	3-5	3-5

10. IF NOISE EXCESS IS GREATER THAN ITEM 9 VALUES IN ANY BAND, WALL OR FLOOR IS UNACCEPTABLE. CHECK HERE

DA FORM 3452-17-R, 10 Aug 70

SOUND TRANSMISSION FROM MER TO ADJOINING ROOM THROUGH COMMON WALL OR FLOOR-CEILING

SOUND TRANSMITTING ROOM CONTROL ROOM   SOUND RECEIVING ROOM MANAGER'S OFFICE

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. AREA S_W OF COMMON TRANSMITTING WALL ☑ OR FLOOR ☐
   15 X 8 = 120 SQ. FT.

2. ROOM CONSTANT R_2 OF REC. RM; ITEM 9 OF DA FORM 3452-14-R

40	60	100	160	200	200	200	200	200

3. RATIO S_W / R_2 (ITEM 1 / ITEM 2)

3.0	2.0	1.2	0.75	0.6	0.6	0.6	0.6	0.6

4. WALL OR FLOOR CORRECTION TERM C FOR ITEM 3 RATIOS, FROM TABLE 32

-5	-4	-2	0	+1	+1	+1	+1	+1

5. PROPOSED WALL OR FLOOR CONSTRUCTION 10" SOLID DENSE CONCRETE BLOCK

6. "TL" OF PROPOSED WALL OR FLOOR. SEE TABLES 21-31 FOR WALL TLs; SEE TABLES 34 - 38 FOR FLOOR-CEILING TLs.

34	35	37	40	45	52	58	63	68

7. "NR" OF PROPOSED WALL OR FLOOR. NR = TL + C
   ITEM 7 = ITEM 6 + ITEM 4

29	31	35	40	46	53	59	64	69

8. SPL ON MER SIDE OF WALL OR FLOOR, FROM ITEM 6 OF DA FORM 3452-16-R FOR ALL EQUIPMENT CONTRIBUTIONS OR APPROPRIATE LINE OF ITEM 7 OF DA FORM 3452-15-R IF FOR ONLY ONE PIECE OF EQUIPMENT FROM ITEM 9 ON PAGE 114

91	87	78	69	64	61	57	53	48

9. SPL IN RECEIVING ROOM DUE TO MER NOISE TRANSMITTED THROUGH WALL OR FLOOR OF ITEM 5 ABOVE.
   $SPL_{REC.\ RM.} = SPL_{MER} - NR$. ITEM 9 = ITEM 8 - ITEM 7

62	56	43	29	18	8	—	—	—

DA FORM 3452-18-R, 10 Aug 70

COMPARISON OF ROOM SPL WITH NOISE CRITERION

SOUND RECEIVING ROOM MANAGER'S OFFICE

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. APPLICABLE ROOM CATEGORY NO. 3 FROM TABLE 2 OF MANUAL
2. SUGGESTED NOISE CRITERION FOR ROOM: NC- 35
3. SPL VALUES CORRESPONDING TO NC VALUE OF ITEM 2; FROM TABLE 1 OF MANUAL

	60	52	45	40	36	34	33	32

4. PROPOSED WALL OR FLOOR CONSTRUCTION BETWEEN MER AND REC. RM; FROM ITEM 5 OF DA FORM 3452-17-R 10" SOLID DENSE CONCRETE BLOCK
5. SPL IN RECEIVING ROOM FOR ITEM 4 WALL; FROM ITEM 9 OF DA FORM 3452-17-R

62	56	43	29	18	8	—	—	—

6. COMPARISON OF ITEM 5 WITH ITEM 3 ABOVE. IF ITEM 5 SPL EXCEEDS ITEM 3 SPL IN ANY FREQUENCY BAND, INSERT THE AMOUNT OF THAT EXCESS IN THE APPROPRIATE SPACE BELOW

—	—	—	—	—	—	—	—	—

7. IF THERE IS NO NOISE EXCESS IN ANY BAND, WALL OR FLOOR DESIGN IS PREFERRED. CHECK HERE ✓
8. IF NOISE EXCESS IS NOT GREATER THAN THE FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS ACCEPTABLE. CHECK HERE ☐

4	4	4	3	2	2	2	2	2

9. IF NOISE EXCESS IS WITHIN FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS MARGINAL. CHECK HERE ☐

5-7	5-7	5-7	4-6	3-5	3-5	3-5	3-5	3-5

10. IF NOISE EXCESS IS GREATER THAN ITEM 9 VALUES IN ANY BAND, WALL OR FLOOR IS UNACCEPTABLE. CHECK HERE ☐

DA FORM 3452-17-R, 10 Aug 70

SOUND TRANSMISSION FROM MER TO ADJOINING ROOM
THROUGH COMMON WALL OR FLOOR-CEILING

SOUND TRANSMITTING ROOM: BOILER ROOM   SOUND RECEIVING ROOM: SECRETARY'S OFFICE

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. AREA S_W OF COMMON TRANSMITTING WALL ☑ OR FLOOR ☐
3 X 8 = 24 SQ. FT.

2. ROOM CONSTANT R_2 OF REC. RM; ITEM 9 OF DA FORM 3452-14-R

24	36	60	96	120	120	120	120	120

3. RATIO S_W/R_2 (ITEM 1 / ITEM 2)

1.0	0.67	0.4	0.25	0.2	0.2	0.2	0.2	0.2

4. WALL OR FLOOR CORRECTION TERM C FOR ITEM 3 RATIOS, FROM TABLE 32

−1	0	+2	+3	+3	+3	+3	+3	+3

5. PROPOSED WALL OR FLOOR CONSTRUCTION 10" SOLID DENSE CONCRETE BLOCK

6. "TL" OF PROPOSED WALL OR FLOOR. SEE TABLES 21-31 FOR WALL TLs; SEE TABLES 34 - 38 FOR FLOOR-CEILING TLs.

34	35	37	40	45	52	58	63	68

7. "NR" OF PROPOSED WALL OR FLOOR. NR = TL + C
ITEM 7 = ITEM 6 + ITEM 4

33	35	39	43	48	55	61	66	71

8. SPL ON MER SIDE OF WALL OR FLOOR, FROM ITEM 6 OF DA FORM 3452-16-R FOR ALL EQUIPMENT CONTRIBUTIONS OR APPROPRIATE LINE OF ITEM 7 OF DA FORM 3452-15-R IF FOR ONLY ONE PIECE OF EQUIPMENT

91	90	89	88	86	84	81	78	75

9. SPL IN RECEIVING ROOM DUE TO MER NOISE TRANSMITTED THROUGH WALL OR FLOOR OF ITEM 5 ABOVE.
$SPL_{REC.\ RM.} = SPL_{MER}$ - NR. ITEM 9 = ITEM 8 - ITEM 7

58	55	50	45	38	29	20	12	4

DA FORM 3452-18-R, 10 Aug 70

COMPARISON OF ROOM SPL WITH NOISE CRITERION

SOUND RECEIVING ROOM SECRETARY'S OFFICE

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. APPLICABLE ROOM CATEGORY NO. 3 FROM TABLE 2 OF MANUAL
2. SUGGESTED NOISE CRITERION FOR ROOM: NC- 35
3. SPL VALUES CORRESPONDING TO NC VALUE OF ITEM 2; FROM TABLE 1 OF MANUAL

	60	52	45	40	36	34	33	32

4. PROPOSED WALL OR FLOOR CONSTRUCTION BETWEEN MER AND REC. RM; FROM ITEM 5 OF DA FORM 3452-17-R 10" SOLID DENSE CONCRETE BLOCK
5. SPL IN RECEIVING ROOM FOR ITEM 4 WALL; FROM ITEM 9 OF DA FORM 3452-17-R

58	55	50	45	38	29	20	12	4

6. COMPARISON OF ITEM 5 WITH ITEM 3 ABOVE. IF ITEM 5 SPL EXCEEDS ITEM 3 SPL IN ANY FREQUENCY BAND, INSERT THE AMOUNT OF THAT EXCESS IN THE APPROPRIATE SPACE BELOW

—	—	—	0	—	—	—	—	—

7. IF THERE IS NO NOISE EXCESS IN ANY BAND, WALL OR FLOOR DESIGN IS PREFERRED. CHECK HERE ☑
8. IF NOISE EXCESS IS NOT GREATER THAN THE FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS ACCEPTABLE. CHECK HERE ☐

4	4	4	3	2	2	2	2	2

9. IF NOISE EXCESS IS WITHIN FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS MARGINAL. CHECK HERE ☐

5-7	5-7	5-7	4-6	3-5	3-5	3-5	3-5	3-5

10. IF NOISE EXCESS IS GREATER THAN ITEM 9 VALUES IN ANY BAND, WALL OR FLOOR IS UNACCEPTABLE. CHECK HERE ☐

120) are essentially the same as those incident on the Control Room wall (Item 8 on page 114). Since the Control Room represents a buffer between the MER and approximately 9 ft of length of the wall of the Secretary's Office, the noise that is transmitted through that 9-ft portion of the wall will be small compared to the noise transmitted through the exposed 3-ft portion of wall, and can be ignored.

f. Door Selections. Three doors (or sets of doors) open into the Boiler Room. The Control Room door can quite obviously be a lightweight metal or glass door and still be compatible with the ¾ in. glass wall of the Control Room. It would be helpful to have a door closer, to help assure that the desired Noise Criterion would be met most of the time.

In Figure B on page 88 a "sound lock" is shown at the main corridor entrance to the Boiler Room. This double-door "sound lock" could be an option depending on how much noise is considered acceptable for the corridor. With a single set of 2-in. thick gasketed doors, it would be quite noisy in the corridor (approximately NC-55 condition) and it would be obvious that a mechanical area lay beyond the doors. When so much effort has gone into quieting the Building Manager's Office it would be inconsistent to have such a noisy approach to that office. With a double set of gasketed doors forming the sound lock, MER noise would be identifiable (approximately an NC-40 condition) but quite acceptable for a corridor. Double doors would be recommended. The doors should be of 2-in. thick solid wood, metal clad if required for fire safety (see Table 27, Footnote 2), or of filled metal panel construction (see Table 24, Footnote 1). Special single doors, such as 6-in. thick industrial type acoustic doors (see Table 24, Footnote 2), could be used if space would not permit the sound lock.

The material of Table 33 is applied to the emergency door to be placed in the wall between the MER and the Computer Room. The area of that door (consider a single door first) might be approximately 20 sq ft while the area of the wall is 480 sq ft. Thus the door area is approximately 4% of the wall area.

Now, the TL of the 10-in. hollow-core concrete block wall is

30	32	34	36	38	43	50	56	61	dB

in the nine octave frequency bands from 31 to 8000 Hz. According to page 113, this is a "preferred" wall, since it meets the desired NC condition in all bands. This wall would still be "acceptable" if it had a 3 dB lower TL in the 500 Hz band. Thus, the composite TL of the wall plus its door could be as much as 3 dB lower than the TL of the wall alone, and still be "acceptable". According to Table 33, for a 4% door area (use the 5% entry in Table 33) the door TL could be approximately 13 dB lower than the wall TL while producing a 3 dB reduction in the TL of the "composite" wall and door. Therefore, subtract 13 dB from the wall TL values given above. The door TL should then equal

17 19 21 23 25 30 37 43 48 dB.

Actually the mid frequency bands are most important because it is there that the wall TL is most crucial. According to Table 27, a well-gasketed 2-in. thick solid wood door would have a TL of

10 15 17 19 20 26 32 37 41 dB.

This door would fail to meet the required TL by 4-5 dB in the mid frequency bands and should not be used.

A well-gasketed 3-in. thick filled metal panel door or a special 4-in. thick industrial-type acoustic door meeting the construction details listed in the footnotes of Table 24 would exceed the above door TL requirement and would be satisfactory. As an alternative, a sound lock involving two gasketed 2-in. thick solid wood doors, as shown in Figure B, would also be satisfactory.

g. Floor-Ceiling Selection. The most crucial spaces near the Boiler Room are the offices and conference rooms located immediately beneath the Boiler Room. A 15 ft x 20 ft office has been considered for this illustration. The accompanying sample DA Forms 3452-17-R and 3452-18-R show the calculations (pages 124-125). A Type 4 floor-ceiling combination (see Table 37) is found to be "preferred". Assumed dimensions for this combination are: 10-in. thick dense concrete floor slab, 24-in. thick air space, 1½-in. thick resiliently supported dense plaster ceiling. Actually, this exact combination of dimensions is not given in Table 37, but it is assumed that this combination is only 1 dB weaker than the 10-in. - 30-in. - 1½-in. combination that is given in the table.

The calculations are not shown here, but it may be estimated that a Type 3 floor-ceiling of 10-in. slab and 24-in. air space with a "High TL" acoustic ceiling would produce 3 dB excess noise in the 125-250 Hz bands and would therefore be rated "acceptable". A Type 2 floor-ceiling of 10-in. slab and 24-in. air space with a

DA FORM 3452-17-R, 10 Aug 70

SOUND TRANSMISSION FROM MER TO ADJOINING ROOM
THROUGH COMMON WALL OR FLOOR-CEILING

SOUND TRANSMITTING ROOM BOILER ROOM

SOUND RECEIVING ROOM TYPICAL OFFICE UNDER BOILER ROOM

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. AREA S_W OF COMMON TRANSMITTING WALL ☐ OR FLOOR ☑

15 X 20 = 300 SQ. FT.

2. ROOM CONSTANT R_2 OF REC. RM; ITEM 9 OF DA FORM 3452-14-R

100	100	150	250	500	500	500	500	500

3. RATIO S_W / R_2 (ITEM 1 / ITEM 2)

3	3	2	1.2	0.6	0.6	0.6	0.6	0.6

4. WALL OR FLOOR CORRECTION TERM C FOR ITEM 3 RATIOS, FROM TABLE 32

-5	-5	-4	-2	+1	+1	+1	+1	+1

5. PROPOSED WALL OR FLOOR CONSTRUCTION TYPE 4 FLOOR-CEILING 10" CONCR. - 24" AIR SPACE - 1½" PLASTER

6. "TL" OF PROPOSED WALL OR FLOOR. SEE TABLES 21-31 FOR WALL TLs; SEE TABLES 34 - 38 FOR FLOOR-CEILING TLs.

43	45	49	53	59	67	73	77	83

7. "NR" OF PROPOSED WALL OR FLOOR. NR = TL + C
ITEM 7 = ITEM 6 + ITEM 4

38	40	45	51	60	68	74	78	84

8. SPL ON MER SIDE OF WALL OR FLOOR, FROM ITEM 6 OF DA FORM 3452-16-R FOR ALL EQUIPMENT CONTRIBUTIONS OR APPROPRIATE LINE OF ITEM 7 OF DA FORM 3452-15-R IF FOR ONLY ONE PIECE OF EQUIPMENT

92	92	92	91	91	89	86	83	78

9. SPL IN RECEIVING ROOM DUE TO MER NOISE TRANSMITTED THROUGH WALL OR FLOOR OF ITEM 5 ABOVE.
$SPL_{REC.\ RM.} = SPL_{MER} - NR$. ITEM 9 = ITEM 8 - ITEM 7

54	52	47	40	31	21	12	5	—

DA FORM 3452-18-R, 10 Aug 70

COMPARISON OF ROOM SPL WITH NOISE CRITERION

SOUND RECEIVING ROOM TYPICAL OFFICE UNDER BOILER ROOM

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. APPLICABLE ROOM CATEGORY NO. 3 FROM TABLE 2 OF MANUAL
2. SUGGESTED NOISE CRITERION FOR ROOM: NC- 30
3. SPL VALUES CORRESPONDING TO NC VALUE OF ITEM 2; FROM TABLE 1 OF MANUAL

	57	48	41	35	31	29	28	27

4. PROPOSED WALL OR FLOOR CONSTRUCTION BETWEEN MER AND REC. RM; FROM ITEM 5 OF DA FORM 3452-17-R TYPE 4 FLOOR-CEILING 10" CONCR. - 24" AIR - 1/2" PLASTER
5. SPL IN RECEIVING ROOM FOR ITEM 4 WALL; FROM ITEM 9 OF DA FORM 3452-17-R

54	52	47	40	31	21	12	5	—

6. COMPARISON OF ITEM 5 WITH ITEM 3 ABOVE. IF ITEM 5 SPL EXCEEDS ITEM 3 SPL IN ANY FREQUENCY BAND, INSERT THE AMOUNT OF THAT EXCESS IN THE APPROPRIATE SPACE BELOW

—	—	—	—	—	—	—	—	—

7. IF THERE IS NO NOISE EXCESS IN ANY BAND, WALL OR FLOOR DESIGN IS PREFERRED. CHECK HERE ☑
8. IF NOISE EXCESS IS NOT GREATER THAN THE FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS ACCEPTABLE. CHECK HERE ☐

4	4	4	3	2	2	2	2	2

9. IF NOISE EXCESS IS WITHIN FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS MARGINAL. CHECK HERE ☐

5-7	5-7	5-7	4-6	3-5	3-5	3-5	3-5	3-5

10. IF NOISE EXCESS IS GREATER THAN ITEM 9 VALUES IN ANY BAND, WALL OR FLOOR IS UNACCEPTABLE. CHECK HERE ☐

regular acoustic ceiling would produce a 6 dB noise excess at the 125-250 Hz bands and would therefore be rated "marginal".

h. Ventilation Opening Treatment. On page 107, the MER noise levels at the north wall are estimated to be

93 92 92 89 87 84 81 79 76 dB

in the nine octave bands. The sound power level (PWL) of a 100 sq ft opening having this SPL is derived in DA Form 3452-20-R (page 127). From the Power Plant Acoustics Manual, DA Forms 3452-12 and 3452-13 are next used (pages 128-129); refer to PPA for discussion of the material used in these latter two forms.

A comparison of the PWL of the escaping noise (Item 6 on page 127) with the PWL criterion values of Items 9 and 11 on page 129 shows that the following noise reduction would be required at the ventilation opening:

(1) to achieve an "acceptable" condition

-- -- -- 4 8 8 6 6 4 dB

(2) to achieve a "marginal" condition

-- -- -- 1 5 5 3 3 1 dB.

Because of at least three uncertainties, it would be suggested that no noise reduction treatment be incorporated into the ventilation opening at the time of construction, but it would be desirable to consider the design of a simple treatment that could be added later if required, in order to achieve approximately 8 dB noise reduction at 500 Hz. The uncertainties are:

(1) actual nighttime background noise may not agree with the values estimated,

(2) the criterion assigned to the hotel occupant might be exceeded slightly with no serious effects if the Boiler Room noise does not have any strongly identifiable pure tone or wavering sounds, and

(3) the pumps, which are the noisiest sources in the middle and upper frequency region, may not produce the noise levels attributed to them.

Since a short muffler or a lined duct turn (see Tables 41 and 42 of PPA) could easily be added to the ventilation opening later,

DA FORM 3452-20-R, 10 Aug 70

NOISE ESCAPE THROUGH OPENINGS IN SOURCE ROOM

ROOM IDENTIFICATION BOILER ROOM

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. SPL AT OPENING

93	92	92	89	87	84	81	79	76

2. AREA OF NOISE ESCAPE OPENING: 100 SQ. FT

3. "AREA FACTOR" FROM TABLE 39 FOR ITEM 2 AREA; SAME VALUE FOR ALL FREQUENCY BANDS.

10	10	10	10	10	10	10	10	10

4. PWL OF NOISE AT OPENING (IN DB RE 10^{-12} WATT). ITEM 4= ITEM 1 + ITEM 3

103	102	102	99	97	94	91	89	86

5. ATTENUATION INSERTED IN PATH TO OUTSIDE (MUFFLER LINED DUCT, LINED BEND, ETC.---FROM MUFFLER MFGR, ASHRAE GUIDE, PPA MANUAL, ETC.)

6. PWL OF ESCAPING NOISE (IN DB RE 10^{-12} WATT). ITEM 6 = ITEM 4 - ITEM 5

103	102	102	99	97	94	91	89	86

DA FORM 3452-12

CRITERION SPL FOR CRITICAL NEIGHBOR

CRITICAL NEIGHBOR *HOTEL OCCUPANT*

CRITICAL TIME: DAY ☐ NIGHT ☑

FREQUENCY BAND IN CPS								
31	63	125	250	500	1000	2000	4000	8000

1. OUTDOOR BACKGROUND SPL AT NEIGHBOR (FROM BACKGROUND MEASUREMENTS OR FROM TABLE 7 AND FIG. 10)

—	58	53	48	43	38	34	30	28

2. LET ~~PLANT~~ MER NOISE EXCEED BACKGROUND BY 5 dB (SEE PARAGRAPH 3-06 b FOR DISCUSSION)

3. TENTATIVE OUTDOOR SPL CRITERION (ITEM 1 + ITEM 2)

—	63	58	53	48	43	39	35	33

4. RECOMMENDED INDOOR SPL CRITERION FOR NEIGHBOR FROM TABLE 6: "NC- 25 "

5. OCTAVE BAND SPL FOR ITEM 4 "NC" CURVE FROM FIG. 9

	54	44	37	31	27	24	22	21

6. APPROXIMATE NOISE REDUCTION PROVIDED BY NEIGHBOR'S BUILDING, FROM TABLE 51 OR SEPARATE STUDY

8	9	10	11	12	13	14	15	16

7. TENTATIVE OUTDOOR SPL CRITERION (ITEM 5 + ITEM 6)

—	63	54	48	43	40	38	37	37

8. FINAL OUTDOOR SPL CRITERION. LOWER SPL IN EACH OCTAVE BAND FROM ITEMS 3 AND 7

—	63	54	48	43	40	38	35	33

DA FORM 3452-13

CRITERION PWL FOR CRITICAL NEIGHBOR

CRITICAL NEIGHBOR HOTEL OCCUPANT DISTANCE 200 FT

	FREQUENCY BAND IN CPS								
	31	63	125	250	500	1000	2000	4000	8000
1. OUTDOOR SPL CRITERION FOR NEIGHBOR (ITEM 8, DATA FORM 12)	-	63	54	48	43	40	38	35	33
2. CONVERSION TERM FROM TABLE 46 OR 47 FOR NEIGHBOR'S DISTANCE	44	44	44	44	44	44	45	46	47
3. TENTATIVE TOTAL PWL CRITERION FOR ALL NOISE SOURCES AT INSTALLATION BEING CONSIDERED (ITEM 1 + ITEM 2)	-	107	98	92	87	84	83	81	80
4. ATTENUATION OF BARRIER, IF ANY (TABLE 48)									
5. ATTENUATION OF WOODS, IF ANY (TABLE 49)									
6. OTHER ATTENUATION, IF ANY									
7. FINAL TOTAL PWL CRITERION FOR "PREFERRED" SOLUTION (ITEM 3 + ITEM 4 + ITEM 5 + ITEM 6)	-	107	98	92	87	84	83	81	80
8. FOR "ACCEPTABLE" SOLUTION, ADD FOLLOWING VALUES TO ITEM 7 PWL (SEE PARAGRAPH 6-02)	4	4	4	3	2	2	2	2	2
9. PWL CRITERION FOR "ACCEPTABLE" SOLUTION (ITEM 7 + ITEM 8)	-	111	102	95	89	86	85	83	82
10. FOR "MARGINAL" SOLUTION, ADD FOLLOWING VALUES TO ITEM 7 PWL (SEE PARAGRAPH 6-02)	7	7	7	6	5	5	5	5	5
11. PWL CRITERION FOR "MARGINAL" SOLUTION (ITEM 7 + ITEM 10)	-	114	105	98	92	89	88	86	85

it would not be unreasonable to postpone a decision on this point until it is found actually necessary. For example, the hotel may be getting ready to air-condition the rooms, thereby closing the outside windows and raising the inside noise levels. That alone would completely remove any need for quieting the escaping noise in this example.

i. Accuracy of Analysis Method. Some uncertainties were mentioned in the material immediately above. If the purchase of a muffler for the ventilation opening can be postponed because of uncertainties in the data, why should a 10-in. floor slab and a 10-in. solid-core concrete block wall be considered with such certainty?

It is necessary to realize that small errors or discrepancies or uncertainties exist with each bit of quoted data, and it is not realistic to rely on the analysis method to the nearest one or two decibels. It is largely for that reason that labels such as "preferred", "acceptable" and "marginal" are used. These offer some gradations in degree of reliability of the final values. It is even possible that if the noise levels of certain specific pieces of mechanical equipment are much lower than the design estimate used in the manual, a design calculated to be "unacceptable" could actually turn out to be "acceptable". This should not be counted on, however, as a means of avoiding a difficult problem.

When numerical values are assigned to PWLs, SPLs, TLs, Room Constants, Noise Criteria, etc., this raises the question of tolerances. Will a given piece of equipment have exactly the SPL estimated for it? Will the TL of a wall actually equal the TL assumed for that wall in the manual? Will the noise be distributed around the inside of a room in exactly the way it is estimated, using the simplified methods and assumptions offered in the manual? Is the reaction of "average" people well enough known to predict with accuracy the noise levels that they will consider acceptable? Will every individual of a group of "average" people respond in the manner assumed for the "average" people? The answer is obviously "no" for each of these questions! Then, to what extent are the results of the evaluation valid?

In most cases the procedure will produce a workable design. The methods and techniques described here are based on many experiences with noise control problems, and these methods have helped produce many satisfactory or improved installations. (Sometimes the economics of a situation may not justify an entirely satisfactory solution for all concerned, but proper use of the analysis can bring a desired and predictable improvement.) The manual will have even served a useful purpose if it reveals that a problem is so serious that the manual alone cannot solve the problem and that special assistance or special designs may be required.

A certain amount of judgement may enter into some design decisions. A suggestion is offered here for helping guide the decision for three types of situations.

(1) When a particular design involves a crucial area, use a conservative approach. Do not weaken the design in order to try "to get by" with something simpler.

(2) When a particular design involves a distinct threat to someone's safety or well-being, use a conservative approach. Examples could be an employee who might suffer hearing loss in an MER because a separate control room was not provided, or a tenant who would not pay his rent because of noise coming from an overhead MER, or a neighbor who might go to court because of disturbing noise. On the other hand, noise in a corridor or a lobby is of less concern.

(3) If a particular design involves a permanent structural member that is not easily modified or corrected later (in the event it should later prove unsatisfactory), use a conservative approach. A poured concrete floor slab is not easily replaced by a new and heavier floor slab. On the other hand, a lightweight movable partition can be changed later if necessary. A muffler can be added later or enlarged later if necessary. Compromises may be justified if the compromised member can be corrected later at relatively small extra cost. Compromises should not be made when the later corrective measure is impossible or inordinately expensive.

4-09. SUMMARY. This section has presented the basic ingredients of airborne noise control, as supplemented by some applicable material from PPA. Noise control is a more quantitatively advanced field than many people would realize. Basically, much of the data and methods given in this manual merely trace the flow of acoustic energy from a source via one or more paths to a receiver. Reasonably predictable values can be attributed to the intensity of the source, to many attenuating and transmitting structures placed in the path of the radiated sound and to the subjective response of people who serve as the receivers of that sound. During the past thirty years, the "art" of acoustics has moved rapidly and with assurance toward a position of practical architectural acoustics and acoustical engineering. The material given in this manual attempts to summarize some of those down-to-earth aspects of acoustics. Tables of data and data forms are given, and real-life examples are used to illustrate the application of these tables and forms. Many practical problems in mechanical equipment noise control can be anticipated and solved with the use of these procedures.

SECTION V. VIBRATION ISOLATION OF MECHANICAL AND ELECTRICAL EQUIPMENT

In Paragraph 2-05 a brief discussion was given on vibration criteria based primarily on the "audibility" of vibrating walls or surfaces. Vibration levels of equipment are not given in the manual, but the vibration isolation recommendations that are given are aimed at achieving acceptable radiated noise levels and essentially imperceptible "feelable" vibration in occupied parts of the building.

5-01. VIBRATION IN BUILDINGS. Almost every structure has many natural frequencies of vibration depending on its mass, stiffness, dimensions, method of mounting, etc. In buildings, many of the natural frequencies of floors, beams, walls, columns, doors, windows, ceilings, etc., frequently fall in the range of 10 to 60 Hz. Typically, much of the mechanical equipment used in buildings operates at speeds that produce noise and vibration in this same frequency range: for example,

600 RPM = 10 Hz
1800 RPM = 30 Hz
3600 RPM = 60 Hz

Thus, it is important to separate or "isolate" these "driving" frequencies of the equipment from the "natural" frequencies of the building, as well as to reduce at all the frequencies the structure-borne noise that is so often disturbing.

For a vibration isolation mount to be effective, its own natural frequency should be lower than the driving frequency of the source (that it is attempting to isolate) by a factor of about 3 to 10, or even more. For many conditions, the higher this ratio, the more effective the isolation. If the natural frequency of the isolation mount just equals the driving frequency of the vibrating source, the system may go into violent oscillation at that frequency, limited only by the damping within the system. Some magnification of the vibration will occur, in fact, as long as the driving frequency is within the range of about 0.3 to 1.4 times the natural frequency of the mount. Below its natural frequency, an isolator provides no isolation.

In view of these frequency characteristics of an isolator, the first important step in the selection of a vibration mount is to be sure that the natural frequency of the isolator is lower (by a factor of at least 3 to 10, if possible) than the driving frequency to be protected. As an aid in taking this first step, the natural frequency (in Hz and in cycles per minute) of a vibration isolator is given in Table 40 as a function of the static deflection (in inches) of the isolator under load.

In most vibration isolator catalogues, there is usually a curve that purports to show the vibration isolation efficiency of a mount. According to that curve, isolation efficiencies of 80%, 90%, 95%, even 98% would appear to be quite commonplace and simple to achieve. The curve usually fails to state that these efficiencies can be achieved only when the isolated system is mounted on an infinitely massive and rigid base. An upper floor slab that deflects up to 1 in. when it is completely loaded hardly qualifies as infinitely rigid. In fact, the actual isolation efficiency of a mount decreases from the idealized maximum as the actual floor deflection increases. As an example, if the isolator static deflection just equals the floor static deflection, the practical limit of isolation efficiency for the mount approaches approximately 50% whereas it would have approached 100% for a completely rigid base. In effect, this means that high deflection floors (usually comparatively lightweight floors or large-span floors) require larger deflection isolators in order to achieve the desired degree of isolation.

Although there is no simple rule-of-thumb, a few suggestions are offered on estimating the desired static deflections of vibration isolators.

(1) For a highly critical installation, the natural frequency of the isolator should be about 1/6th to 1/10th the driving frequency that is to be controlled (or even lower), and the static deflection of the isolator should not be less than about 6 to 10 times the static deflection of the floor when the equipment load is added.

(2) For a less critical situation, the natural frequency of the isolator should be about 1/3rd to 1/6th the driving frequency that is to be controlled (of even lower), and the static deflection of the isolator should not be less than about 3 to 6 times the static deflection of the floor when the equipment is added.

Of course, when practical or economic limitations prohibit application of these suggestions, compromises have to be made. The need for compromise is illustrated by the vibration isolation of a cooling tower. Suppose a 75-HP cooling tower is mounted directly above an executive office that qualifies for an NC-25 criterion (in other words, it is a critical installation). Suppose the propeller fan runs at 240 RPM (a reasonable speed for a 10-ft to 14-ft blade diameter), and suppose the roof deck deflects an additional 1 in. when the fully loaded cooling tower is installed. According to one of the suggestions, the natural frequency of an isolator should be about 1/6th the driving frequency, or 40 RPM which is approximately 0.7 Hz. In Table 40, a spring with a 20 in. static deflection would meet this suggestion. Such a spring would stand about 4 ft tall when uncompressed -- hardly practical! According to the second suggestion, the static deflection of the isolator should be about 6 to 10 times the floor deflection, or 6 to 10 in. This, at least, is possible although it still represents a spring about 2 ft tall when uncompressed. This illustrates one of the reasons why large cooling towers are usually installed on dunnage that is supported directly off the tops of the columns of the building instead of on roof decks. The compression of the columns is fairly negligible when the cooling tower load is added. A resulting 5 in. or 6 in. static deflection of the springs is a reasonable compromise decision. Note (from Table 40) that these springs would have a natural frequency of approximately 80 CPM or 1.3 Hz which is removed by a factor of 3 from the driving frequency of 240 CPM or 4 Hz. The cooling tower represents an extreme example because of the low shaft speed.

Before leaving this example, however, it should be pointed out that the next higher "driving" frequency of the cooling tower fan is the blade passage frequency, which would be about 40 Hz for a 10-bladed fan (240 RPM x 10 blades/60 = 40 Hz). A 5-in. to 6-in. static deflection spring with a natural frequency of 1.3 Hz can provide good isolation at 40 Hz (when properly used). Thus, noise or vibration at the blade passage frequency would be controlled by the spring. As an incidental point, people would not "hear" the noise of the cooling tower at the shaft speed of 240 RPM or 4 Hz, but they might feel the vibration caused by an unisolated and unbalanced fan. Hence, an isolator whose natural frequency is only 1/3rd that of the driving frequency would be worthwhile in this case.

For most other equipment, more reasonable values occur. For example, suppose a reciprocating-compressor refrigeration machine operates at 1200 RPM and it is to be located over a critical area, and the floor deflection might be 1/4 in. when the machine is installed. According to one of the approaches, the static deflection of the isolator should be such that its natural frequency is 1/6th to 1/10th the driving frequency; in other words, a static deflection of between 0.9 and 2.4 in. By the second approach, the static deflection of the isolator should be about 6 to 10 times the floor deflection; in other words, about 1.5 to 2.5 in. Choosing the upper end of the range, a value of 2 to 2.5 in. static deflection would represent a practical isolator for this installation.

In the material that follows, a fairly complete collection of vibration isolation mounting details are given. These are based on experience with many actual installations. Paragraph 5-02 names some general conditions applicable to all mounting systems, Paragraphs 5-03 through 5-07 describe in general terms five "types of mounting systems" to be called upon specifically for use with certain equipment, and Paragraphs 5-08 through 5-20 give detailed recommendations for the vibration isolation of specific equipment, some of which require the mounting assemblies described in Paragraphs 5-03 through 5-07. Paragraphs 5-21 through 5-23 refer to piping, connections and auxiliary equipment.

5-02. GENERAL CONDITIONS. In the vibration isolation recommendations that follow, several general conditions are assumed. These are summarized here.

a. <u>Building Uses.</u> Isolation recommendations are given for three general equipment locations: (1) "on grade slab", (2) "on upper floor above non-critical area", and (3) "on upper floor above critical area". It is assumed that the building under consideration is an occupied building involving many spaces that would require or deserve the low noise and vibration environments of such buildings as hotels, hospitals, office buildings and the like, as characterized by Categories 1-4 of Table 2. Hence, the recommendations are aimed at providing the required low vibration levels throughout the building. Since an on-grade slab usually represents a more rigid base than is provided by a framed upper floor, the vibration isolation recommendations can generally be somewhat relaxed. Of course, vibration isolation treatments must be the very best when a high quality occupied area is located immediately under the MER, as compared with the case where a "buffer zone" or non-critical area is located between the MER and the critical area.

If a building is intended to serve entirely for such uses as those of Categories 5 and 6 of Table 2, the recommendations given here are too severe and can be simplified at the user's discretion.

b. Floor Slab Thickness. It is assumed that MER upper floor slabs will be constructed of dense concrete of minimum 140-150 lb/cu ft density, or if lighter concrete is used, the thickness will be increased to provide the equivalent total mass of the specified floor. For large MERs containing arrays of large and heavy equipment, it is assumed that the floor slab thickness will be in the range of 8 to 12 in., with the greater thicknesses required by the greater floor loads. For smaller MERs containing smaller collections of lighter-weight but typical equipment, floor slab thicknesses of 6 to 10 in. are assumed. For occasional locations of one or a very few pieces of small high speed equipment (say 1800 RPM or higher) having no reciprocating action, floor slabs of 4 to 6 in. may be used with reasonable expectation of satisfactory results. However, for reciprocating-action machines operating at the lower speeds (say, under 1200 RPM), any reduced floor slab thicknesses from those listed above begin to invite problems. There is no clear cross-over from "acceptable" to "unacceptable" in terms of floor slab thickness, but each reduction in thickness increases the probability of later difficulties due to vibration.

The thicknesses mentioned here are based on experience with the "acoustics" of equipment installations. These statements on thicknesses are in no way intended to represent structural specifications for a building.

"Housekeeping pads" under the equipment are assumed, but the height of these pads is not to be used in calculating the thickness of the floor slab.

c. Steel Spring Isolators. As a general rule, unhoused free-standing stable steel springs are preferred over housed spring assemblies. The housed spring is frequently an "unstable spring"; that is, it will tilt sidewise as it is loaded, and the housing is required to keep it in a somewhat upright orientation. In so doing, however, the housing (or its internal lining of neoprene strips) tends to short-circuit the coils of the spring or even bind the spring when it is badly "tilted" inside the housing. All of this reduces the effectiveness of the spring. Further, the housing frequently so encloses the spring that it is hidden from view, and inspection is made difficult.

On the other hand, the stable steel spring has a larger diameter and requires more space (the diameter is comparable to the compressed height), but it is clearly in view for critical inspection (if not recessed inside an enclosing pocket of a concrete inertia block).

d. Steel Springs Plus Pads. It is a specific recommendation that whenever a steel spring is used, at least one and preferably two pads of ribbed or waffle-pattern neoprene or a minimum 1-in. thick compressed glass fiber pad be used in series with the spring (either under the base of the spring or on top of the spring). It is suggested that this pad be considered in addition to the anti-skid ribbed pad that is frequently supplied already cemented to the bottom of the spring base. Grout or building dirt frequently fills up the cavities or grooves of the anti-skid pad and it loses the effectiveness it might once have had.

From a simple point of view, a steel spring is a coiled-up rod of steel that connects a piece of noisy equipment to a floor. The coiled rod is very effective in isolating low frequency vibration from the floor, but, like any rod, it will transmit high frequency noise from the machine to the floor. A rubber or neoprene or glass fiber isolator, however, is most effective at high frequency. Thus, if a steel spring is used in series with a neoprene or glass fiber pad, both the low frequency and the high frequency structure-borne noise are reduced.

In the material that follows, whenever a steel spring is specified, noise isolation pads should be used in series with that spring (even though this statement is not repeated with every spring specification)! Although there are times when this is not necessary, the exceptions are too few to discuss, so they will be ignored.

For many equipment installations, there is no need to bolt down the isolation mounts to the floor because the smooth operation of the machine and the weight of the complete assembly keep the system from moving. For some systems, however, it may be necessary to restrain the equipment from "creeping" across the floor. In these situations, it is imperative that the hold-down bolts not short-circuit the pads. A suggested restraining arrangement is illustrated in Figure 13.

e. Structural Ties, Rigid Connections. Each piece of isolated equipment must be free of any structural tie or rigid connection that can short-circuit the isolation joint. Electrical conduit should be long and "floppy" so that it does not offer any resistance or constraint to the free movement of the equipment. Piping should be resiliently supported or contain flexible connections as discussed later. Limit stops, shipping bolts and leveling bolts on spring isolators should be set and inspected to insure that they are not inadvertently short-circuiting the spring mounts.

All building trash should be removed from under the isolated base of the equipment. This seemingly innocent and unnecessary plea becomes more meaningful when a waste basketfull of loose grout, 2x4s, nuts, bolts, soft drink bottles, beer cans, welding rods, pipes and pipe couplings are removed from beneath a single base, after the contractor has left the job but could not understand why the isolated equipment was still noisy on the floor below.

It is recommended that large 2-in. to 4-in. clearances be provided under all isolated equipment bases in order to facilitate inspection and removal of trash from under the base.

5-03. TYPE I MOUNTING ASSEMBLY. The specified equipment should be mounted rigidly on a large integral concrete inertia block. (Unless specified otherwise, all concrete referred to in this manual should have a density of at least 140-150 lb/cu ft.) The length and the width of the inertia block should be at least 50% greater than the length and width of the supported equipment. Mounting brackets for stable steel springs should be located off the sides of the inertia block at or near the height of the vertical center-of-gravity of the combined completely assembled equipment and concrete block. If necessary, curbs or pedestals should be used under the base of the steel springs in order to bring the top of the loaded springs up to the center-of-gravity position. As an alternative, the lower portion of the concrete inertia block can be lowered into a pit or cavity in the floor so that the steel springs will not have to be mounted on curbs or pedestals. In any event, the clearance between the floor (or all the surfaces of the pit) and the concrete inertia block shall be at least 4 in. and provision should be allowed to check this clearance at all points under the block.

The ratio of the weight of the concrete block to the total weight of all the supported equipment (including the weight of any attached filled piping up the point of the first pipe hanger) shall be in accordance with the recommendations given in the paragraph and table for the particular equipment requiring this mounting assembly. The inertia block adds stability to the system and reduces motion of the system in the vicinity of the driving frequency. For reciprocating machines or for units involving large starting torques, the inertia block provides much-needed stability.

The static deflection of the free-standing stable steel springs shall be in accordance with the recommendations given in the paragraph and table for the particular equipment. There shall be adequate clearance all around the springs to assure no contact between any spring and any part of the mounted assembly for any possible alignment or position of the installed inertia block.

5-04. TYPE II MOUNTING ASSEMBLY. This mount is the same as the Type I Mount in all respects except (1) the mounting brackets and the top of the steel springs shall be located as high as practical on the concrete ineria block but not necessarily as high as the vertical center-of-gravity position of the assembly, and (2) the clearance between the floor and the concrete inertia block shall be at least 2 in.

If necessary, the steel springs can be recessed into pockets in the concrete block, but clearances around the springs should be large enough to assure no contact between any spring and any part of the mounted assembly for any possible alignment or position of the installed inertia block. Provision must be made to allow positive visual inspection of the spring clearance in its recessed mounting.

When this type mounting is used for a pump, the concrete inertia block can be given a T-shape in plan and the pipes to and from the pump can be supported rigidly with the pump onto the "wings" of the T. In this way the pipe elbows will not be placed under undue stress.

The weight of the inertia block and the static deflection of the mounts shall be in accordance with the recommendations given in the table for the particular equipment.

5-05. TYPE III MOUNTING ASSEMBLY. The equipment or the assembly of equipment should be mounted on a sufficiently stiff steel frame that the entire assembly can be supported on flexible point supports without fear of distortion of the frame or mis-alignment of the equipment. The frame is then mounted on resilient mounts, either steel springs or neoprene-in-shear mounts or isolation pads, as the static deflection would require. If the equipment frame itself already has adequate stiffness, no additonal framing is required and the isolation mounts may be applied directly to the base of the equipment.

The vibration isolated assembly should have enough clearance under and all around the equipment to prohibit contact with any structural part of the building during operation. If the equipment has large starting and stopping torques and the isolation mounts have large static deflections, consideration should be given to providing limit stops on the mounts. Limit stops might also be desired for large deflection isolators if the filled and unfilled weights of the equipment are very different.

5-06. TYPE IV MOUNTING ASSEMBLY. The equipment should be mounted on an array of "pad mounts". The pads may be of compressed glass fiber or of multiple layers of ribbed-neoprene or waffle-pattern neoprene of sufficient height and of proper stiffness to support the load while meeting the static deflection recommended in the applicable accompanying tables. Cork, cork-neoprene or felt pad materials may be used if their stiffness characteristics are known and providing they can be replaced periodically whenever they have become sufficiently compacted that they no longer provide adequate isolation.

The floor should be grouted or shimmed to assure a level base for the equipment and therefore a predictable uniform loading on the isolation pads. The pads should be loaded in accordance with the loading rates recommended by the pad manufacturer for the particular densities or durometers involved. In general, most of these pads are intended for load rates of 30-60 psi, and if they are underloaded (for example, at less than about 10 psi) they will not be performing at their maximum effectiveness.

5-07. TYPE V MOUNTING ASSEMBLY (FOR PROPELLER-TYPE COOLING TOWERS). Large, low-speed propeller-type cooling towers located on roof decks of large buildings may produce serious vibration in their buildings if adequate vibration isolation is not provided. In extreme cases, the vibration may be evident two or three floors below the cooling towers.

It is recommended that the motor, drive shaft, gear reducer and propeller be mounted as rigidly as possible on a "unitized" structural support and that this entire assembly be isolated from the remainder of the tower with stable steel springs in accordance with Table 46. Adequate clearance between the propeller tips and the cooling tower shroud should be provided to allow for starting and stopping vibrations of the propeller assembly. Several of the cooling tower manufacturers provide isolated assemblies as described here.

In addition, where the cooling tower is located on a roof deck directly over an acoustically critical area, the structure-borne waterfall noise may be objectionable and this can be reduced with the use of 3 layers of ribbed or waffle-pattern neoprene located between the base of the cooling tower and the supporting structure of the building. This latter treatment is usually not necessary if there is a noncritical area immediately under the cooling tower.

A single-treatment alternate to the combined two treatments mentioned above is the isolation of the entire cooling tower assembly on stable steel springs, also in accordance with Table 46. The springs should be in series with at least two layers of ribbed or waffle-pattern neoprene if there is an acoustically critical area immediately below the cooling tower (or within about 25 ft horizontally on the floor immediately under the tower). It may be desirable to provide limit stops on these springs to limit movement of the tower when it is emptied.

Pad materials, when used, should not be short-circuited by bolts or rigid connections. A schematic of an acceptable clamping arrangement for pad mounts is shown in Figure 14. Cooling tower piping should be vibration isolated in accordance with suggestions given for piping.

5-08. TABLE OF RECOMMENDED VIBRATION ISOLATION DETAILS. The accompanying Table M, on page 143, shows the general form of a table that is used to summarize the recommendations for each type of equipment. A brief description of the form is given here.

The three columns on the left of Table M define the equipment conditions covered by the recommendations: location, "rating" and speed of the equipment. The "rating" is given by a "power" range for some equipment, "cooling capacity" for some and "heating capacity" for some. The rating and speed ranges generally cover the range of equipment included in the noise measurement survey described in Section III. Subdivisions in rating and speed are made to accommodate variations in the isolation details.

The three columns on the right of the table summarize three basic groups of recommendations: Column 1, the type of mounting (from Paragraphs 5-03 through 5-07); Column 2, the suggested minimum ratio of the weight of the inertia block (when required) to the total weight of all the equipment mounted on the inertia block; and Column 3, the suggested minimum static deflection of the isolator to be used.

Regarding the weight of the inertia block, the larger weight of the range given should be applied: (1) where the nearby critical area is <u>very</u> critical -- such as Category 1 or 2 of Table 2, (2) where the speed of the equipment is near the lower limit of the speed range given, or (3) where the rating of the equipment is near the upper limit of the rating range. Conversely, the lower end of the weight range may be applied: (1) where the nearby critical area is less critical -- such as Category 3 or 4 of Table 2, (2) where the speed is near the upper limit of the speed range, or (3) where the rating is near the lower limit of the rating range.

Regarding the static deflection of the isolators, these minimum values are keyed to the approximate span of the floor beams; that is, as the floor span increases, the floor deflection increases; and therefore the isolator deflection must increase. The specified minimum deflection in effect specifies the type of isolator that can be used:

TABLE M

FORMAT FOR PRESENTING RECOMMENDED

VIBRATION ISOLATION MOUNTING DETAILS

EQUIPMENT CONDITIONS			MOUNTING RECOMMENDATIONS				
EQUIPMENT LOCATION	RATING	SPEED RANGE (RPM)	COLUMN 1	COLUMN 2	COLUMN 3		
					30'	40'	50'
ON GRADE SLAB							
ON UPPER FLOOR ABOVE NON-CRITICAL AREA							
ON UPPER FLOOR ABOVE CRITICAL AREA							

COL 1: MOUNTING TYPE (SEE TEXT)
COL 2: MINIMUM RATIO OF WEIGHT OF INERTIA BLOCK TO TOTAL WEIGHT OF SUPPORTED LOAD
COL 3: MINIMUM STATIC DEFLECTION OF STABLE STEEL SPRINGS IN INCHES FOR INDICATED FLOOR SPAN IN FEET

Deflection Range	Isolator
1/2 in. and over	Steel Spring or Air Spring+
0.3 to 0.5 in.	Double deflection neoprene-in-shear
0.10 to 0.25 in.	Neoprene-in-shear, or 1-in. to 2-in. thick compressed glass fiber pads, or 2 to 4 layers ribbed or waffle-pattern neoprene pads

5-09. RECIPROCATING-COMPRESSOR REFRIGERATION EQUIPMENT. The recommended vibration isolation details for this equipment are summarized in Table 41, given in Section VII at the rear of the manual. These recommendations apply also to the drive unit used with the reciprocating compressor.

Pipe connections from this assembly to other equipment should contain flexible connections (see Paragraph 5-22) and piping should be given resilient support (see Paragraph 5-21).

5-10. ROTARY-SCREW-COMPRESSOR REFRIGERATION EQUIPMENT. The recommended vibration isolation details for this equipment are summarized in Table 42. Piping to and from this equipment should be given resilient support (Paragraph 5-21).

5-11. CENTRIFUGAL-COMPRESSOR REFRIGERATION EQUIPMENT. The recommended vibration isolation details for this equipment, including the drive unit and the condenser and chiller tanks, are summarized in Table 43. Piping to and from this assembly should be given resilient support (Paragraph 5-21).

+Air Springs are excellent as low-frequency isolators for special problems. They require a pressure-controlled air supply and occasional inspection for proper operation. They may be used instead of steel springs, especially for low-frequency isolation where springs become large in size.

5-12. ABSORPTION-TYPE REFRIGERATION EQUIPMENT. The recommended vibration isolation details for this equipment are summarized in Table 44. Piping should be given resilient support (Paragraph 5-21).

5-13. BOILERS. The recommended vibration isolation details for boilers are summarized in Table 45. These apply for boilers with integrally attached blowers, but these do not necessarily apply to blowers on separate mounts.

Piping should be given resilient support in accordance with Paragraph 5-21. A flexible connection or a thermal expansion joint should be installed in the exhaust breaching between the boiler and the exhaust stack.

5-14. STEAM VALVES. Steam valves are usually supported entirely on their pipes; refer to Paragraph 5-21 for the resilient support of piping, including steam valves.

5-15. COOLING TOWERS. The recommended vibration isolation details for propeller-type cooling towers are summarized in Table 46. Additional details for the installation are given in Paragraph 5-07 which describes the Type V mounting assembly.

The recommended vibration isolation details for centrifugal-fan cooling towers are summarized in Table 47. Cooling tower piping should be isolated in accordance with Paragraph 5-21.

5-16. MOTOR-PUMP ASSEMBLIES. Recommended vibration isolation details for motor-pump units are summarized in Table 48. Electrical connections to the motors should be made with long "floppy" lengths of flexible armored cable, and piping should be resiliently supported as in Paragraph 5-21. For most situations, a good isolation mounting of the piping will overcome the need for flexible connections in the pipe.

An important function of the concrete inertia block (Type II mounting) is its stabilizing effect against undue "bouncing" of the pump assembly at the instant of starting. This gives better long-time protection to the associated piping.

These same recommendations may be applied to other motor-driven rotary devices such as centrifugal-type air compressors and motor-generator sets in the power range up to a few hundred horsepower.

5-17. STEAM TURBINES. Table 49 provides a set of general vibration isolation recommendations for steam-turbine-driven rotary equipment, such as gears, generators or centrifugal-type gas compressors. When a steam turbine is used to drive centrifugal-compressor refrigeration equipment, refer to the material given in Table 43; and when it is used to drive reciprocating-compressor refrigeration equipment or reciprocating-type gas compressors, refer to the recommendations given in Table 41.

Piping associated with the steam turbine and the remainder of the assembly should be vibration isolated according to Paragraph 5-21.

5-18. GEARS. When a gear is involved in a drive system, vibration isolation should be provided in accordance with recommendations given in the manual for either the main power drive unit or the driven unit, whichever imposes the more stringent isolation conditions. The more stringent conditions are usuallly those requiring the largest inertia block or the largest static deflection for the spring mounts. Tables 41,43 and 49 may possibly be involved in the comparison.

5-19. TRANSFORMERS. Recommended vibration isolation details for indoor transformers are given in Table 50. In addition, power leads to and from the transformers should be as flexible as possible. (Switchgear may be mounted on isolation mounts having approximately one-half the static deflection given in Table 50, except that no isolation is required for most on-grade installations.)

In outdoor locations, earth-borne vibration to nearby neighbors is usually not a problem, so no vibration isolation is suggested. If vibration should become a problem, the transformer could be installed on neoprene or compressed glass fiber pads having 1/4 in. static deflection.

5-20. AIR COMPRESSORS. Recommended mounting details for centrifugal-type air compressors of less than 100 HP are the same as those given for motor-pump units in Table 48. The same recommendations would apply for small (under 10 HP) reciprocating-type air compressors. For reciprocating-type air compressors (with more than two cylinders) in the 10-50 HP range, follow the recommendations given in Table 41 for the particular conditions.

For 10-100 HP one- or two-cylinder reciprocating-type air compressors, the recommendations of Table 51 apply. This equipment is a potentially serious source of low frequency vibration in a building if it is not isolated. In fact, the compressor should not be located in certain parts of the building, even if it is vibration isolated. The "forbidden" locations are indicated in Table 51.

When these compressors are used, all piping should contain flexible connections and the electrical connections should be made with flexible armored cable. Refer to Paragraph 5-22 for flexible connections and to Paragraph 5-21 for resilient pipe supports.

5-21. RESILIENT PIPE SUPPORTS. All piping in the MER that is connected to vibrating equipment should be supported from resilient ceiling hangers or from floor-mounted resilient supports. As a general rule, the first three pipe supports nearest the vibrating equipment should have a static deflection of at least one-half the static deflection of the mounting system used with the equipment. Beyond the third pipe support, the static deflection can be reduced to approximately 1/2 in. for the remainder of the pipe run in the MER.

When a pipe passes through the MER wall, a minimum 1 in. clearance should be provided between the pipe and the hole in the wall. The pipe should be supported on either side of the hole, so that the pipe does not rest on the wall. The clearance space should then be stuffed with fibrous filler material and sealed with a non-hardening caulking compound.

Vertical pipe chases through a building should not be located beside acoustically critical areas (Categories 1-3 in Table 2). If they are located beside critical areas, pipes should be resiliently mounted from the walls of the pipe chase for a distance of at least 20 ft beyond each such area.

Pipes to and from the cooling tower should be resiliently supported when the piping passes within 20 ft of acoustically critical areas (Categories 1-3 of Table 2). Steam pipes should be resiliently supported for their entire length of run inside the building. Resilient mounts should have a static deflection of at least 1/2 in.

In highly critical areas, domestic water pipes and waste lines can be isolated with the use of 1/4 in. to 1/2 in. thick wrappings of felt pads under the pipe strap or pipe clamp.

As mentioned earlier, whenever a steel spring isolater is used, it should be in series with a neoprene or glass fiber isolater. For ceiling hangers, a neoprene washer or grommet should always be included; and if the pipe hangers are near very critical areas, the hanger should be a combination hanger that contains both a steel spring and a neoprene-in-shear mount.

During inspection, check that the hanger rods are not touching the sides of the isolator housing and thereby shorting-out the spring.

5-22. FLEXIBLE PIPE CONNECTIONS. To be at all effective, a flexible pipe connection should have a length that is approximately 6 to 10 times its diameter. Tie rods should not be used to bolt the two end flanges of a flexible connection together. Flexible connections are either of the bellows-type or are made up of wire-reinforced neoprene piping, sometimes fitted with an exterior braided jacket to confine the neoprene. These connections are useful when the equipment is subject to fairly high-amplitude vibration, such as for reciprocating-type compressors. Flexible connections generally are not necessary when the piping and its equipment are given thorough and compatible vibration isolation.

5-23. NON-VIBRATING EQUIPMENT. When an MER is located directly over or near a critical area, it is usually desirable to isolate most of the "non-vibrating equipment" with a simple mount made up of one or two pads of neoprene or a 1-in. or 2-in. layer of compressed glass fiber. Heat exchangers, hot water heaters, water storage tanks, large ducts and some large pipe stands may not themselves be noise sources, yet their pipes or their connections to vibrating sources transmit small amounts of vibrational energy that they then may transmit into the floor. A simple minimum isolation pad will usually prevent this noise transfer.

5-24. SUMMARY. In this section, fairly complete vibration isolation mounting details are laid out for all the equipment included in the manual. Most of these details have been developed and proven over many years of use. Although all the entries of the accompanying Tables 41-51 probably have not been tested in actual equipment installations, the schedules are fairly self-consistent in terms of various locations and degrees of required isolation. Hence, the mounting details are considered quite realistic and fairly reliable. They are not extravagant in their make-up when considered in the light of the extremely low vibration levels required to achieve near-inaudibility.

The noise and vibration control methods used in the manual are designed to be simple to follow and to put into use. If these methods and recommendations are carried out, with appropriate attention to detail, most equipment installations will be tailored to the specific needs of the building and will give very satisfactory results acoustically.

SECTION VI - REFERENCES

1. "Power Plant Acoustics", Technical Manual TM 5-805-9, 14 December 1968, Department of the Army, Washington D. C., 20314.

2. Latest applicable issue of "ASHRAE Guide and Data Book", chapter on Sound Control; American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.; 345 East 47th Street, New York, New York 10017

3. "Revised Criteria for Noise in Buildings", Leo L. Beranek; Noise Control Magazine, Vol.3, pp. 19-27, January 1957. Also Chapter 20 of Reference [4] below.

4. "Noise Reduction", Leo L. Beranek, Editor; McGraw-Hill Book Company (1960).

5. "Speech Privacy in Buildings", W. J. Cavanaugh, W. R. Farrell, P. W. Hirtle, B. G. Watters, Jour. Acoustical Society of America, Vol. 34, No. 4 pages 475-492, April 1962.

6. "Acoustics", Leo L. Beranek; McGraw-Hill Book Company, page 420, (1954). Values adjusted by "Criteria for Evaluating Your Noise Problem", Leo L. Beranek, ASME Manuscript 69-DE-40, May 1969.

7. "How to Estimate Plant Noises", Irving Heitner, Hydrocarbon Processing, December 1968, Vol. 47, No. 12, pages 67-74.

8. "Test Procedure for Airborne Noise Measurements on Rotating Electric Machinery", IEEE Publication No. 85, February 1965. The data are repeated in the NEMA Publication MG1-1967 on "Motors and Generators".

9. "Transformer, Regulators and Reactors", NEMA Standards Publication No TRI-1968; National Electrical Manufacturers Association, 155 East 44th Street, New York, New York 10017.

10. ISO/TC 43 (SECRETARIAT - 283) 413E "Proposal for a Test Code for the Measurement of the Airborne Noise Emitted by Rotating Machinery", when approved; ANSI SI.13/155 "Proposed U.S.Standard Methods for the Measurement of Sound Levels and Sound Pressure Levels", when approved; or other applicable standards.

11. Latest applicable annual bulletin of "Performance Data of Architectural Acoustical Materials", Acoustical and Insulating Materials Association, 205 West Touhy Avenue, Park Ridge, Illinois 60068.

SECTION VII - DATA FORMS, TABLES, AND FIGURES

7-01. LIST OF DATA FORMS

7-02. LIST OF TABLES

7.03. LIST OF FIGURES

DA FORM 3452-14-R, 10 Aug 70

ROOM CONSTANT OF SOURCE ROOM OR RECEIVER ROOM

ROOM NO. OR DESIGNATION ______________________________

1. AVERAGE ROOM DIMENSIONS (IN FT.)
   LENGTH __________ WIDTH ____________ HEIGHT __________
2. VOLUME OF ROOM ________________ CU. FT.
3. TOTAL INTERIOR SURFACE AREA OF ROOM ____________ SQ. FT.
4. AREA OF PLANNED ACOUSTIC TREATMENT+ ____________ SQ. FT.
5. PERCENT AREA COVERED BY ACOUSTIC TREATMENT _______ %
   (100 x Item 4/Item 3)
6. "ROOM LABEL" FOR ITEM 5 FROM PART A OF TABLE 19
   ____
7. FOR ITEMS 2 AND 6, ROOM CONSTANT FROM FIGURE 12
   R = ______________ SQ. FT. FOR 500 - 8000 Hz
8. CHECK ACOUSTIC ABSORPTION TREATMENT:

		☐ NONE OR NRC = 0.65 - 0.74	☐ NRC = 0.75 - 0.85
THEN, FOR	31 Hz	0.2 R = ________	0.2 R = ________
	63 Hz	0.2 R = ________	0.3 R = ________
	125 Hz	0.3 R = ________	0.5 R = ________
	250 Hz	0.5 R = ________	0.8 R = ________

9. ROOM CONSTANT FOR ALL OCTAVE BANDS, IN SQ. FT.#
   (Repeat appropriate values from Items 7 and 8)

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

+Add 50% of floor area to Item 4 if floor is carpeted or has drapes or upholstered furniture. Treat this as NRC = 0.65 material.

#Add to all bands any area always open to the outside, ie having 100% absorption.

DA FORM 3452-15-R, 10 Aug 70 SHEET 1 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT

EQUIPMENT IDENTIFICATION

TYPE ______________________________ HP______ RPM_____

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. SPL OF EQUIPMENT AT 3-FT DISTANCE, FROM TABLE____OF MANUAL OR OTHER SOURCE

2. SPECIAL ADJUSTMENTS, IF ANY, TO ITEM 1 DATA.
   EXPLAIN: ______________________________

3. RESULTING SPL AFTER ADJUSTMENTS

4. DISTANCE FROM EQUIPMENT TO VARIOUS WALLS AND SURFACES OF INTEREST (ALL DISTANCES IN FT).
   NORTH WALL ________ SOUTH WALL __________ EAST WALL ________ WEST WALL ________

   CEILING______________ FLOOR+____________ (+Assume 3 ft unless different)

   SURFACE "A" (IDENTIFY):________________ DISTANCE ________

   SURFACE "B" (IDENTIFY):________________ DISTANCE ________

   SURFACE "C" (IDENTIFY):________________ DISTANCE ________

   SURFACE "D" (IDENTIFY):________________ DISTANCE ________

5. ROOM CONSTANT FOR THIS ROOM (FROM ITEM 9 OF DA FORM 3452-14-R).

DA FORM 3452-15-R, 10 Aug 70 SHEET 2 OF 2

MECHANICAL EQUIPMENT ROOM SPL DUE TO EQUIPMENT (CONT.)

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

6. SPL REDUCTION FOR VARIOUS DISTANCES AND ROOM CONSTANTS, FROM TABLE 20 OR FIGURE 11 (FILL IN SPACES ONLY FOR SURFACES OF INTEREST)

	31	63	125	250	500	1000	2000	4000	8000
NORTH									
SOUTH									
EAST									
WEST									
CEIL.									
FLOOR+									
"A"									
"B"									
"C"									
"D"									

+Floor value is "O" for all bands, if distance is 3 ft

7. SPL AT SURFACES OF INTEREST FOR THIS PIECE OF EQUIPMENT ONLY (ITEM 7 = ITEM 3 - ITEM 6)

	31	63	125	250	500	1000	2000	4000	8000
NORTH									
SOUTH									
EAST									
WEST									
CEIL.									
FLOOR									
"A"									
"B"									
"C"									
"D"									

DA FORM 3452-16-R, 10 Aug 70

SUMMATION OF SPLs DUE TO ALL EQUIPMENT
IN MECHANICAL EQUIPMENT ROOM (MER)

MER NO. OR DESIGNATION ______________________

CHECK WALL OR SURFACE INVOLVED IN THIS SUMMATION

NORTH WALL ☐ SOUTH WALL ☐ EAST WALL ☐ WEST WALL ☐ CEILING ☐ FLOOR ☐

OR OTHER SURFACE DESIGNATION ______________________

IN NUMBERED SPACES BELOW, IDENTIFY EQUIPMENT WHOSE NOISE LEVELS CONTRIBUTE TO TOTAL SPL AT INDICATED WALL OR SURFACE. IN SPL SPACES, INSERT SPL VALUES AT THAT SURFACE DUE TO THAT EQUIPMENT, AS TAKEN FROM ITEM 7 OF DA FORM 3452-15-R.

	OCTAVE FREQUENCY BAND IN Hz								
	31	63	125	250	500	1000	2000	4000	8000
1.									
2.									
3.									
4.									
5.									

6. TOTAL SPL AT INDICATED WALL OR SURFACES DUE TO ABOVE EQUIPMENT, USING DECIBEL SUMMATION RULES OF TABLE 18. FOR FLOOR, USE HIGHEST READING IN EACH BAND FROM ITEMS 1-5.

DA FORM 3452-17-R, 10 Aug 70

SOUND TRANSMISSION FROM MER TO ADJOINING ROOM
THROUGH COMMON WALL OR FLOOR-CEILING

SOUND TRANSMITTING ROOM ________________ SOUND RECEIVING ROOM ________________

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. AREA S_W OF COMMON TRANSMITTING WALL ☐ OR FLOOR ☐

   ________ X ________ = ____________ SQ. FT.

2. ROOM CONSTANT R_2 OF REC. RM; ITEM 9 OF DA FORM 3452-14-R

3. RATIO S_W / R_2 (ITEM 1 / ITEM 2)

4. WALL OR FLOOR CORRECTION TERM C FOR ITEM 3 RATIOS, FROM TABLE 32

5. PROPOSED WALL OR FLOOR CONSTRUCTION ________________

6. "TL" OF PROPOSED WALL OR FLOOR. SEE TABLES 21-31 FOR WALL TLs; SEE TABLES 34 - 38 FOR FLOOR-CEILING TLs.

7. "NR" OF PROPOSED WALL OR FLOOR. NR = TL + C
   ITEM 7 = ITEM 6 + ITEM 4

8. SPL ON MER SIDE OF WALL OR FLOOR, FROM ITEM 6 OF DA FORM 3452-16-R FOR ALL EQUIPMENT CONTRIBUTIONS OR APPROPRIATE LINE OF ITEM 7 OF DA FORM 3452-15-R IF FOR ONLY ONE PIECE OF EQUIPMENT

9. SPL IN RECEIVING ROOM DUE TO MER NOISE TRANSMITTED THROUGH WALL OR FLOOR OF ITEM 5 ABOVE.
   $SPL_{REC.\ RM.} = SPL_{MER} - NR$. ITEM 9 = ITEM 8 - ITEM 7

DA FORM 3452-18-R, 10 Aug 70

COMPARISON OF ROOM SPL WITH NOISE CRITERION

SOUND RECEIVING ROOM ______________________________

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. APPLICABLE ROOM CATEGORY NO.______ FROM TABLE 2 OF MANUAL
2. SUGGESTED NOISE CRITERION FOR ROOM: NC- ___________
3. SPL VALUES CORRESPONDING TO NC VALUE OF ITEM 2; FROM TABLE 1 OF MANUAL

4. PROPOSED WALL OR FLOOR CONSTRUCTION BETWEEN MER AND REC. RM; FROM ITEM 5 OF DA FORM 3452-17-R ______________________________
5. SPL IN RECEIVING ROOM FOR ITEM 4 WALL; FROM ITEM 9 OF DA FORM 3452-17-R

6. COMPARISON OF ITEM 5 WITH ITEM 3 ABOVE. IF ITEM 5 SPL EXCEEDS ITEM 3 SPL IN ANY FREQUENCY BAND, INSERT THE AMOUNT OF THAT EXCESS IN THE APPROPRIATE SPACE BELOW

7. IF THERE IS NO NOISE EXCESS IN ANY BAND, WALL OR FLOOR DESIGN IS PREFERRED. CHECK HERE ☐
8. IF NOISE EXCESS IS NOT GREATER THAN THE FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS ACCEPTABLE. CHECK HERE ☐

4	4	4	3	2	2	2	2	2

9. IF NOISE EXCESS IS WITHIN FOLLOWING VALUES IN ANY BAND, WALL OR FLOOR IS MARGINAL. CHECK HERE ☐

5-7	5-7	5-7	4-6	3-5	3-5	3-5	3-5	3-5

10. IF NOISE EXCESS IS GREATER THAN ITEM 9 VALUES IN ANY BAND, WALL OR FLOOR IS UNACCEPTABLE. CHECK HERE ☐

DA FORM 3452-19-R, 10 Aug 70

ESTIMATED SPL AT 3-FT DISTANCE INDOORS WHEN SOURCE PWL IS KNOWN

EQUIPMENT IDENTIFICATION

TYPE ________________________________ HP______ RPM_____

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. PWL FOR EQUIPMENT IN DB RE 10^{-12} WATT. IF PWL IS REFERRED TO 10^{-13} WATT, SUBTRACT 10 DB FROM ALL VALUES.

2. APPROXIMATE OVERALL DIMENSIONS OF EQUIPMENT, IN FEET. IGNORE ANY PORTION OBVIOUSLY NOT PRODUCING OR RADIATING NOISE.

LENGTH ________ WIDTH __________ HEIGHT _________

3. ADD THE THREE DIMENSIONS OF ITEM 2; DIVIDE THE SUM BY 6. THE RESULT IS APPROXIMATELY THE "RADIUS" OF THE EQUIPMENT.

SUM _____________ DIVIDED BY 6 = ____________ FT.

4. ADD 3 FT TO THE ITEM 3 VALUE. THIS GIVES THE DISTANCE FROM THE ASSUMED "ACOUSTIC CENTER" OF THE UNIT, WHICH IS APPROXIMATELY 3 FT FROM THE NEAREST PART OF THE UNIT.

ITEM 3 __________ + 3 = ___________ FT.

5. ROOM CONSTANT OF MECHANICAL EQUIPMENT ROOM, FROM ITEM 9 OF DA FORM 3452-14-R

6. DETERMINE "RELATIVE SPL" FROM FIG. 11 OF MANUAL FOR THE DISTANCE DIMENSION OF ITEM 4 ABOVE, FOR EACH OF THE ROOM CONSTANT VALUES OF ITEM 5 ABOVE. INSERT "REL SPL" AND PROPER SIGN (+ OR -) IN SPACES BELOW.

7. APPROXIMATE SPL AT 3-FT DISTANCE. SPL = PWL + REL SPL. ITEM 7 = ITEM 1 + ITEM 6 (CAUTION: KEEP CORRECT SIGNS!) THIS SPL AT THE NORMALIZED 3-FT DISTANCE MAY BE INSERTED INTO ITEM 1 OF DA FORM 3452-15-R AND THIS EQUIPMENT GIVEN THE SAME TREATMENT AS ALL OTHER INDOOR EQUIPMENT IN THE ANALYSIS PROCEDURE.

DA FORM 3452-20-R, 10 Aug 70

NOISE ESCAPE THROUGH OPENINGS IN SOURCE ROOM

ROOM IDENTIFICATION ______________________________

OCTAVE FREQUENCY BAND IN Hz								
31	63	125	250	500	1000	2000	4000	8000

1. SPL AT OPENING

2. AREA OF NOISE ESCAPE OPENING: ____________________ SQ. FT

3. "AREA FACTOR" FROM TABLE 39 FOR ITEM 2 AREA; SAME VALUE FOR ALL FREQUENCY BANDS.

4. PWL OF NOISE AT OPENING (IN DB RE 10^{-12} WATT). ITEM 4 = ITEM 1 + ITEM 3

5. ATTENUATION INSERTED IN PATH TO OUTSIDE (MUFFLER LINED DUCT, LINED BEND, ETC.---FROM MUFFLER MFGR, ASHRAE GUIDE, PPA MANUAL, ETC.)

6. PWL OF ESCAPING NOISE (IN DB RE 10^{-12} WATT). ITEM 6 = ITEM 4 - ITEM 5

TABLE 1

OCTAVE BAND SOUND PRESSURE LEVEL (SPL) VALUES
ASSOCIATED WITH THE NOISE CRITERION
CURVES OF FIGURE 1 AND TABLE 2

NOISE CRITERION CURVES	63 HZ	125 HZ	250 HZ	500 HZ	1000 HZ	2000 HZ	4000 HZ	8000 HZ
NC-15	47	36	29	22	17	14	12	11
NC-20	51	40	33	26	22	19	17	16
NC-25	54	44	37	31	27	24	22	21
NC-30	57	48	41	35	31	29	28	27
NC-35	60	52	45	40	36	34	33	32
NC-40	64	56	50	45	41	39	38	37
NC-45	67	60	54	49	46	44	43	42
NC-50	71	64	58	54	51	49	48	47
NC-55	74	67	62	58	56	54	53	52
NC-60	77	71	67	63	61	59	58	57
NC-65	80	75	71	68	66	64	63	62

TABLE 2

CATEGORY CLASSIFICATION AND SUGGESTED NOISE CRITERION RANGE FOR INTRUDING MECHANICAL EQUIPMENT NOISE AS HEARD IN VARIOUS INDOOR FUNCTIONAL ACTIVITY AREAS

CATEGORY	AREA (AND ACOUSTIC REQUIREMENTS)	NOISE CRITERION
1	Bedrooms, sleeping quarters, hospitals, residences, apartments, hotels, motels, etc. (for sleeping, resting, relaxing).	NC-20 to NC-30
2	Auditoriums, theaters, large meeting rooms, large conference rooms, base communication centers, churches, chapels, etc. (for very good listening conditions).	NC-20 to NC-30
3	Private offices, small conference rooms, classrooms, libraries, etc. (for good listening conditions).	NC-30 to NC-35
4	Large offices, reception areas, PX, retail shops and stores, cafeterias, restaurants, etc. (for fair listening conditions).	NC-35 to NC-40
5	Lobbies, laboratory work spaces, drafting and engineering rooms, maintenance shops such as for electrical equipment, etc. (for moderately fair listening conditions).	NC-40 to NC-50
6	Kitchens, laundries, shops, garages, machinery spaces, power plant control rooms, etc. (for minimum acceptable speech communication, no risk of hearing damage).	NC-45 to NC-65

TABLE 3

SPEECH INTERFERENCE LEVELS ("PSIL"):
AVERAGE NOISE LEVELS# (IN DB) THAT PERMIT
BARELY ACCEPTABLE SPEECH INTELLIGIBILITY
AT THE DISTANCES AND VOICE LEVELS SHOWN

Distance (ft)	Voice Level: Normal	Raised	Very Loud	Shouting
½	74	80	86	92
1	68	74	80	86
2	62	68	74	80
4	56	62	68	74
6	53	59	65	71
8	50	56	62	68
10	48	54	60	66
12	46	52	58	64
16	44	50	56	62

PSIL (Speech Interference Level in "Preferred" Octave Bands) is arithmetic average of noise levels in the 500, 1000 and 2000 Hz octave frequency bands. PSIL values apply for average male voices (reduce values 5 dB for female voice), with speaker and listener facing each other, using unexpected word material. PSIL values may be increased 5 dB when familiar material is spoken. Distances assume no nearby reflecting surface to aid the speech sounds.

TABLE 4

ESTIMATED SOUND PRESSURE LEVELS (IN DB) AT 3-FT DISTANCE
DUE TO VARIOUS TYPES OF REFRIGERATION MACHINES

OCTAVE BAND (HZ)	31	63	125	250	500	1000	2000	4000	8000
MACHINE TYPE AND COOLING CAPACITY (TONS):									
PACKAGED CHILLERS WITH RECIPROCATING COMPRESSORS									
10-50	82	86	84	86	87	86	84	80	75
51-175	85	90	89	92	93	92	90	86	81
PACKAGED CHILLERS WITH ROTARY-SCREW COMPRESSORS									
100-300	70	76	80	92	89	85	80	75	73
PACKAGED CHILLERS WITH CENTRIFUGAL COMPRESSORS									
Under 500	87	88	89	90	90	91	92	87	80
500 and more	89	90	91	92	93	97	99	94	87
ABSORPTION MACHINES									
All sizes	88	91	86	86	86	83	80	77	72

TABLE 5

ESTIMATED SOUND PRESSURE LEVELS (IN DB) AT 3-FT DISTANCE
DUE TO BOILERS AND STEAM VALVES

OCTAVE BAND (HZ)	31	63	125	250	500	1000	2000	4000	8000
BOILERS (50-2000 BHP) #									
	92	92	92	89	86	83	80	77	74
STEAM VALVES (WITH THERMAL INSULATION)									
	70	70	70	70	75	80	85	90	95

Distance should be measured from the front surface of the boiler.

TABLE 6

APPROXIMATE OCTAVE BAND SOUND POWER LEVELS OF PROPELLER TYPE COOLING TOWER IN dB re 10^{-12} WATT

OCTAVE FREQUENCY BAND (HZ)	4 to 8 HP	9 to 16 HP	17 to 32 HP	33 to 64 HP	65 to 128 HP	129 to 256 HP
31	96	99	102	105	108	111
63	101	104	107	110	113	116
125	101	104	107	110	113	116
250	96	99	102	105	108	111
500	93	96	99	102	105	108
1000	89	92	95	98	101	104
2000	86	89	92	95	98	101
4000	82	86	89	92	95	98
8000	78	81	84	87	90	93

TABLE 7

APPROXIMATE OCTAVE BAND SOUND POWER LEVELS OF CENTRIFUGAL TYPE COOLING TOWER IN dB re 10^{-12} WATT

OCTAVE FREQUENCY BAND (HZ)	4 to 8 HP	9 to 16 HP	17 to 32 HP	33 to 64 HP	65 to 128 HP	129 to 256 HP
31	85	88	91	94	97	100
63	86	89	92	95	98	101
125	86	89	92	95	98	101
250	84	87	90	93	96	99
500	83	86	89	92	95	98
1000	81	84	87	90	93	96
2000	82	85	88	91	94	97
4000	76	79	82	85	88	91
8000	69	72	75	78	81	84

TABLE 8

DISTANCE TERM [10 log ($2\pi D^2$) - 10 dB]
FOR CALCULATING SPL OUT TO A DISTANCE OF 100 FT
FROM A NOISE SOURCE OF POWER PWL
SPL = PWL - DISTANCE TERM
where PWL is in dB re 10^{-12} watts

DISTANCE D (ft)	DISTANCE TERM (dB)	DISTANCE D (ft)	DISTANCE TERM (dB)
$1\frac{1}{4}$	0	19-21	24
2	4	22-23	25
3	8	24-26	26
4	10	27-29	27
5	12	30-33	28
6	14	34-37	29
7	15	38-42	30
8	16	43-47	31
9	17	48-53	32
10	18	54-59	33
11	19	60-67	34
12-13	20	68-75	35
14	21	76-84	36
15-16	22	85-94	37
17-18	23	95-100	38

TABLE 9

DISTANCE TERM, INCLUDING ABSORPTION LOSSES,
FOR CALCULATING SPL FOR DISTANCES OF 100 FT TO 10,000 FT
FROM A NOISE SOURCE OF POWER PWL
SPL = PWL - DISTANCE TERM
where PWL is in dB re 10^{-12} watts

DISTANCE D (ft)	DISTANCE TERM (TO NEAREST dB) FOR OCTAVE FREQUENCY BAND (Hz) 31-250	500	1000	2000	4000	8000
100	38	38	38	38	39	39
112	39	39	39	39	40	41
125	40	40	40	40	41	42
141	41	41	41	41	42	43
158	42	42	42	42	43	44
178	43	43	43	44	44	46
200	44	44	44	45	46	47
224	45	45	45	46	47	48
252	46	46	46	47	48	50
282	47	47	47	48	49	51
316	48	48	48	49	50	53
355	49	49	49	50	52	54
400	50	50	51	51	53	56
448	51	51	52	52	54	57
504	52	52	53	54	56	59
564	53	53	54	55	57	61
632	54	54	55	56	59	63
712	55	56	56	57	60	65
800	56	57	57	58	62	67
900	57	58	58	60	64	70

(continued on next page)

TABLE 9 (continued)

DISTANCE D (ft)	DISTANCE TERM (TO NEAREST dB) FOR OCTAVE FREQUENCY BAND (Hz) 31-250	500	1000	2000	4000	8000
1000	58	59	59	61	66	72
1120	59	60	61	62	68	75
1260	60	61	62	64	70	78
1410	61	62	63	65	73	81
1580	62	63	64	67	75	85
1780	63	64	66	68	77	89
2000	64	65	67	70	79	93
2240	65	67	68	72	82	97
2520	66	68	70	74	85	102
2820	67	69	71	75	89	108
3160	68	70	72	77	92	114
3560	69	72	74	80	96	120
4000	70	73	76	82	101	128
4480	71	74	77	84	105	136
5040	72	76	79	87	111	145
5640	73	77	81	90	116	154
6320	74	78	83	93	123	165
7120	75	80	85	96	130	178
8000	76	82	87	100	138	191
9000	77	83	90	104	146	207
10000	78	85	92	108	155	222

TABLE 10

APPROXIMATE CORRECTIONS TO AVERAGE SPLs FOR DIRECTIONAL EFFECTS OF COOLING TOWERS

(Add these decibel corrections to the average SPL calculated for a given distance from the tower. Do not apply these corrections for close-in positions, such as less than 10 ft. Also, these corrections apply when there are no reflecting or obstructing surfaces that would modify the normal radiation of sound from the tower.)

OCTAVE BAND (Hz)	31	63	125	250	500	1000	2000	4000	8000
CENTRIFUGAL-FAN BLOW-THROUGH TYPE									
Front	+3	+3	+2	+3	+4	+3	+3	+4	+4
Side	0	0	0	-2	-3	-4	-5	-5	-5
Rear	0	0	-1	-2	-3	-4	-5	-6	-6
Top	-3	-3	-2	0	+1	+2	+3	+4	+5
AXIAL-FLOW BLOW-THROUGH TYPE									
Front	+2	+2	+4	+6	+6	+5	+5	+5	+5
Side	+1	+1	+1	-2	-5	-5	-5	-5	-4
Rear	-3	-3	-4	-7	-7	-7	-8	-11	-8
Top	-5	-5	-5	-5	-2	0	0	+2	+1
INDUCED-DRAFT PROPELLER-TYPE									
Front	0	0	0	+1	+2	+2	+2	+3	+3
Side	-2	-2	-2	-3	-4	-4	-5	-6	-6
Top	+3	+3	+3	+3	+2	+2	+2	+1	+1
"UNDERFLOW" FORCED-DRAFT PROPELLER-TYPE									
Any side	-1	-1	-1	-2	-2	-3	-3	-4	-4
Top	+2	+2	+2	+3	+3	+4	+4	+5	+5

TABLE 11

ESTIMATED CLOSE-IN SOUND PRESSURE LEVELS (IN DB) FOR THE INTAKE AND DISCHARGE OPENINGS OF VARIOUS COOLING TOWERS

(3-ft to 5-ft Distance)

OCTAVE BAND (Hz)	31	63	125	250	500	1000	2000	4000	8000
CENTRIFUGAL-FAN BLOW-THROUGH TYPE									
Intake	85	85	85	83	81	79	76	73	68
Discharge	80	80	80	79	78	77	76	75	74
AXIAL-FLOW BLOW-THROUGH TYPE (INCLUDING "UNDERFLOW" TYPE)									
Intake	97	100	98	95	91	86	81	76	71
Discharge	88	88	88	86	84	82	80	78	76
PROPELLER-FAN INDUCED DRAFT TYPE									
Intake	97	98	97	94	90	85	80	75	70
Discharge	102	107	103	98	93	88	83	78	73

TABLE 12

ESTIMATED SOUND PRESSURE LEVELS (IN DB) OF PUMPS (AT 3-FT DISTANCE INDOORS) AS A FUNCTION OF POWER AND SPEED

PUMP RPM	RATED HP	OCTAVE BAND FREQUENCY - HZ 31	63	125	250	500	1000	2000	4000	8000
1600-3600	Under 12	77	77	80	82	82	80	77	74	69
	12-24	80	80	83	85	85	83	80	77	72
	25-49	83	83	86	88	88	86	83	80	75
	50-99	86	86	89	91	91	89	86	83	78
	100-199	89	89	92	94	94	92	89	86	81
	200-400	92	92	95	97	97	95	92	89	84
	Over 400	95	95	98	100	100	98	95	92	97
900-1599	Under 12	72	72	75	77	77	75	72	69	64
	12-24	75	75	78	80	80	78	75	72	67
	25-49	78	78	81	83	83	81	78	75	70
	50-99	81	81	84	86	86	84	81	78	73
	100-199	84	84	87	89	89	87	84	81	76
	200-400	87	87	90	92	92	90	87	84	79
	Over 400	90	90	93	95	95	93	90	87	82
450-899	Under 12	70	70	73	75	75	73	70	67	62
	12-24	73	73	76	78	78	76	73	70	65
	25-49	76	76	79	81	81	79	76	73	68
	50-99	79	79	82	84	84	82	79	76	71
	100-199	82	82	85	87	87	85	82	79	74
	200-400	85	85	88	90	90	88	85	82	77
	Over 400	88	88	91	93	93	91	88	85	80

TABLE 13

ESTIMATED SOUND PRESSURE LEVELS (IN DB) OF ELECTRIC MOTORS
(AT 3-FT DISTANCE INDOORS) AS A FUNCTION
OF POWER AND SPEED

MOTOR RPM	RATED HP	31	63	125	250	500	1000	2000	4000	8000
2000-4000	Under 12	73	74	78	82	83	83	82	76	69
	12-24	78	79	83	87	88	88	87	81	74
	25-49	83	84	88	92	93	93	92	86	79
	50-99	87	88	92	96	97	97	96	90	83
	100-200	90	91	95	99	100	100	99	93	86
	Over 200	93	94	98	102	103	103	102	96	89
1000-1990	Under 12	68	69	73	77	78	78	77	71	64
	12-24	73	74	78	82	83	83	82	76	69
	25-49	78	79	83	87	88	88	87	81	74
	50-99	82	83	87	91	92	92	91	85	78
	100-200	85	86	90	94	95	95	94	88	81
	Over 200	88	89	93	97	98	98	97	91	84
450-990	Under 12	64	65	69	73	74	74	73	67	60
	12-24	69	70	74	78	79	79	78	72	65
	25-49	74	75	79	83	84	84	83	77	70
	50-99	78	79	83	87	88	88	87	81	74
	100-200	81	82	86	90	91	91	90	84	77
	Over 200	84	85	89	93	94	94	93	87	80

Octave band frequency columns (31 to 8000) are in HZ.

TABLE 14

ESTIMATED SOUND PRESSURE LEVELS (IN DB)
OF STEAM TURBINES (AT 3-FT DISTANCE)
AS A FUNCTION OF POWER RATING

RATED HP	RATED KW	31	63	125	250	500	1000	2000	4000	8000
500-1500	333-1000	88	93	95	91	87	87	88	85	80
1501-5000	1001-3333	90	95	97	93	89	90	92	89	85
5001-15000	3334-10000	92	97	99	95	91	93	96	93	90

TABLE 15

ESTIMATED SOUND PRESSURE LEVELS (IN DB) OF GEARS AT 3-FT DISTANCE

VALUES APPLY TO 125-8000 HZ OCTAVE BANDS
DEDUCT 3 DB FOR 63 HZ OCTAVE BAND
DEDUCT 6 DB FOR 31 HZ OCTAVE BAND

SPEED OF SLOWER GEAR SHAFT (RPM)	POWER RATING OF GEAR IN HP							
	125 to 249	250 to 499	500 to 999	1000 to 1999	2000 to 3999	4000 to 7999	8000 to 15999	16000 to 32000
125-249	94	95	96	97	98	99	100	101
250-499	95	96	97	98	99	100	101	102
500-999	96	97	98	99	100	101	102	103
1000-1999	97	98	99	100	101	102	103	104
2000-3999	98	99	100	101	102	103	104	105
4000-7999	99	100	101	102	103	104	105	106
8000-16000	100	101	102	103	104	105	106	107

TABLE 16

ESTIMATED MAXIMUM SOUND PRESSURE LEVELS OF A TRANSFORMER AT 3-FT DISTANCE

First, obtain or estimate the NEMA Sound Level Rating for the Transformer. (This is an average of several A-scale readings taken at certain specified positions at a 1-ft distance from the transformer surfaces or at a 6-ft distance from the forced-air ventilated surfaces.)

OCTAVE FREQUENCY BAND (Hz)	Add the following values to the NEMA Sound Level Rating. The resulting values are sound pressure levels in dB re 0.0002 microbar
31	0
63	5
125	10
250	17
500	14
1000	9
2000	4
4000	-1
8000	-6

TABLE 17

ESTIMATED SOUND PRESSURE LEVELS (IN DB) AT 3-FT DISTANCE

DUE TO RECIPROCATING AND CENTRIFUGAL AIR COMPRESSORS

AIR COMPRESSOR POWER RANGE (HP)	OCTAVE BAND CENTER FREQUENCY - HZ								
	31	63	125	250	500	1000	2000	4000	8000
1-2	85	83	83	83	86	89	89	89	84
3-9	90	86	86	86	89	92	92	92	87
10-100	95	89	89	89	92	95	95	95	90

TABLE 18

RULES FOR ADDING SPL OR PWL CONTRIBUTIONS BY "DB ADDITION"

1. For adding any two decibel levels together -

When two decibel values differ by:	Add the following amount to the higher value:
0 or 1 dB	3 dB
2 or 3 dB	2 dB
4 to 8 dB	1 dB
9 dB or more	0 dB

2. If there are several levels of the same value, they may be added as follows:

No. of equal levels	Add
2	3 dB
3	5 dB
4	6 dB
5	7 dB
6-7	8 dB
8	9 dB
9-10	10 dB
N	10 log N dB

3. The individual components can be added in any order. The total, using this simplified procedure, will give an answer that is correct to within 1 dB.

4. When combining the frequency contributions of different sources, add only noise levels from the same octave frequency band.

TABLE 19

ACOUSTIC TREATMENT DETAILS FOR USE WITH FIGURES 11 AND 12 IN ESTIMATING ROOM CONSTANT

(See pages 31-33 of text)

PART A. SURFACE COVERAGE OF ACOUSTIC MATERIAL

Percentage of Total Room Surface Area Covered with Absorption Material	Room Label on Figure 2 Curves
0%	"Live Room"
10%	"Medium-Live Room"
15-20%	"Average Room"
30-35%	"Medium-Dead Room"
50-60%	"Dead Room"

PART B. LOW FREQUENCY CORRECTION TO "R"

Octave Band (Hz)	Corrected R to be used in Figure 1 for NRC = 0.65 - 0.74 and if there is no acoustic absorption	NCR = 0.75 - 0.85
31	0.2 R	0.2 R
63	0.2 R	0.3 R
125	0.3 R	0.5 R
250	0.5 R	0.8 R

Notes:

1. "NRC" is "noise reduction coefficient." It represents the average of the acoustic absorption coefficients of the material for the four frequency bands 250, 500, 1000 and 2000 Hz. This does not necessarily mean that noise is reduced by the amount of the NRC value. NRC values are published for all acoustical materials manufactured and distributed by members of the Acoustical and Insulating Materials Association, 205 W. Touhy Avenue, Park Ridge, Illinois 60068.

2. An NRC of 0.65 to 0.74 can be met by most perforated, fissured or textured acoustic tiles or panels of 3/4-in. or 1-in. thickness or by most perforated panels containing at least 1 in. thick layers of glass fiber or mineral wool.

3. An NRC of 0.75 - 0.85 can be met by most 2-in. thick layers of acoustic absorption material or by most 3/4-in. or 1-in. thick acoustic materials spaced at least 2 in. away from the wall or 10 in. away from the ceiling from which they are supported.

TABLE 20

REDUCTION OF SPL (IN DB) IN GOING FROM NORMALIZED 3-FT DISTANCE TO A GREATER DISTANCE "D" IN A ROOM HAVING A ROOM CONSTANT "R"

ROOM CONSTANT "R" (in sq. ft)	DISTANCE "D" (IN FT) FROM EQUIPMENT							
	5	10	15	20	30	40	60	80
100	0	1	1	1	1	1	1	1
200	1	1	1	1	1	1	1	1
320	2	2	2	2	2	2	2	2
500	2	3	3	4	4	4	4	4
700	2	3	4	4	4	5	5	5
1000	2	4	5	5	6	6	6	6
2000	3	6	7	7	8	8	8	8
3200	4	7	8	8	9	10	11	11
5000	4	8	9	10	11	12	12	13
7000	4	8	10	11	12	13	14	15
10000	4	9	11	12	13	14	15	17
20000	5	10	12	14	16	17	19	20
50000	5	10	13	16	18	21	23	25
INFINITE	5	11	14	17	20	23	26	29

TABLE 21

APPROXIMATE TRANSMISSION LOSS (IN DB) OF DENSE POURED CONCRETE# OR SOLID-CORE CONCRETE BLOCK OR MASONRY

OCTAVE FREQUENCY BAND (HZ)	THICKNESS OF CONCRETE OR MASONRY (IN.) 4	6	8	10	12	16
	APPROXIMATE SURFACE WEIGHT (LB/SQ FT) 48	72	96	120	144	192
31	29	32	33	34	35	36
63	32	33	34	35	36	37
125	34	35	36	37	38	39
250	35	36	38	40	41	43
500	37	40	43	45	47	50
1000	42	46	50	52	54	56
2000	49	53	56	58	59	61
4000	55	58	61	63	64	66
8000	60	63	66	68	69	70

TABLE 22

APPROXIMATE TRANSMISSION LOSS (IN DB) OF HOLLOW-CORE DENSE# CONCRETE BLOCK OR MASONRY

OCTAVE FREQUENCY BAND (HZ)	THICKNESS OF CONCRETE OR MASONRY (IN.) 4	6	8	10	12	16
	APPROXIMATE SURFACE WEIGHT (LB/SQ FT) 28	36	44	52	60	76
31	24	26	28	30	31	32
63	29	30	31	32	32	33
125	32	33	33	34	34	35
250	33	34	35	36	36	37
500	34	35	36	38	39	42
1000	37	39	41	43	45	48
2000	42	46	48	50	52	55
4000	49	52	54	56	58	60
8000	55	57	59	61	63	65

\# 1. "Dense" concrete = 140-150 lb/cu ft density

2. For applications involving "transmission loss" as an acoustic requirement, do not use "cinder block" or other lightweight porous block material.

TABLE 23

APPROXIMATE TRANSMISSION LOSS (IN DB)
OF CONVENTIONAL STUD-TYPE PARTITIONS[1]

OCTAVE FREQUENCY BAND (HZ)	STANDARD WOOD STUD PARTITION[2]	STAGGERED WOOD STUD PARTITION[3]	IMPROVEMENT WITH INSULATION[4]
31	10	12	1
63	15	17	1
125	20	22	2
250	26	30	3
500	34	38	4
1000	40	44	4
2000	45	47	5
4000	43	45	5
8000	45	47	5

1. Partitions made with 2-1/2 in. to 3-1/2 in. wide steel studs will approximate the values given here for wood-stud construction.

2. 2x4 wood studs on 16 in. centers, nailed to 2x4 wood plates; 5/8 in. thick gypsum board nailed on both sides of studs; fill and tape joints and edges, finish as desired.

3. 2x4 wood studs staggered on 2x6 wood plates, alternate studs supporting separate walls of 5/8 in. thick gypsum board; all-nailed construction, studs for each wall on 16 in. centers; fill and tape joints and edges, finish as desired.

4. Installation of either (a) 1/2 in. thick glass fiber board or metal spring clips between studs and gypsum board, or (b) min. 1-1/2 in. thick limply supported lightweight insulation in air space between partitions will produce improvement indicated. For staggered partition, use of both types of insulation will produce twice the improvement shown in the table. Add the "improvement values" to the TL of the stud partition to which the insulation has been added.

TABLE 24

APPROXIMATE TRANSMISSION LOSS (IN DB)
OF FILLED METAL PANEL PARTITION AND
TYPICAL INDUSTRIAL ACOUSTIC DOORS

OCTAVE FREQUENCY BAND (HZ)	FILLED METAL PANEL PARTITION[1]	TYPICAL ACOUSTIC DOORS[2] 4" THICK	6" THICK
31	19	27	33
63	22	29	35
125	26	33	37
250	31	36	39
500	36	42	46
1000	43	47	50
2000	48	53	56
4000	50	56	61
8000	52	59	65

1. Constructed of two 18 ga. steel panels filled with 3 in. thickness of 6-8 lb/cu ft glass fiber or rock wool; joints and edges sealed air-tight.

2. Industrial type acoustic doors typically constructed of sheet steel exterior facings, 1 in. plywood under the sheet steel, densely packed filler of glass fiber or rock wool; heavy framing and hardware; double gasket seals all around door edges. "Studio-type" acoustic doors usually not as thick and heavy, with more elaborate finish details.

TABLE 25

APPROXIMATE TRANSMISSION LOSS (IN DB) OF GLASS WALLS OR WINDOWS #

OCTAVE FREQUENCY BAND (HZ)	THICKNESS OF GLASS (IN.) 1/8	1/4	1/2	3/4
	APPROXIMATE SURFACE WEIGHT (LB/SQ FT) 1½	3	6½	10
31	0	5	11	14
63	5	11	17	20
125	11	17	23	24
250	17	23	25	25
500	23	25	26	27
1000	25	26	27	28
2000	26	27	28	29
4000	27	28	30	33
8000	28	30	36	39

Special laminated safety glass containing one or more viscoelastic layers sandwiched between glass panels will yield 3-8 dB higher values than given here for single thicknesses of glass; available in approximately 1/4 in. to 5/8 in. thicknesses.

TABLE 26

APPROXIMATE TRANSMISSION LOSS (IN DB) OF DOUBLE-GLASS WINDOWS #

OCTAVE FREQUENCY BAND (HZ)	GLASS - AIR SPACE - GLASS THICKNESSES (INCHES) ¼ - ¼ - ¼	¼ - 1½ - ¼	¼ - 6 - ¼
31	13	14	15
63	18	19	20
125	23	23	24
250	24	25	28
500	24	27	31
1000	26	31	37
2000	28	34	40
4000	30	37	43
8000	36	42	46

Thermal-insulation double-glass windows typically have 1/4 in. to 1 in. sealed air space between 1/4 in. to 3/8 in. glass panels. For larger air spaces, individual glass panels should be mounted separately in rubber or neoprene gaskets. For large temperature differences across the window, provide desiccant or small ventilation ports in the inner space to eliminate condensation on the cold glass.

TABLE 27

APPROXIMATE TRANSMISSION LOSS (IN DB)

OF WOOD[1] OR PLYWOOD

(4 LB/SQ FT/IN. SURFACE DENSITY)

OCTAVE FREQUENCY BAND (HZ)	THICKNESS OF WOOD OR PLYWOOD (IN.) 1/4	1/2	1	2[2]	4
	APPROXIMATE SURFACE WEIGHT (LB/SQ FT) 1	2	4	8	16
31	0	0	5	10	16
63	0	4	11	15	18
125	5	10	16	17	19
250	11	15	18	19	20
500	16	17	19	20	26
1000	18	19	20	26	32
2000	19	20	26	32	37
4000	20	26	32	37	41
8000	26	32	37	41	45

1. Wood construction requires tongue-and-groove joints, overlapping joints, or sealing of joints against air leakage. For intermediate thicknesses, interpolate between thicknesses given in table.

2. For 2 in. solid wood doors that are well-gasketed all around, these values of TL may be used.

TABLE 28

APPROXIMATE TRANSMISSION LOSS (IN DB)

OF DENSE# PLASTER

(9 LB/SQ FT/IN. SURFACE DENSITY)

OCTAVE FREQUENCY BAND (HZ)	THICKNESS OF PLASTER (IN.) 1/2	3/4	1	1-1/2	2
	APPROXIMATE SURFACE WEIGHT (LB/SQ FT) 4-1/2	7	9	13	18
31	9	12	15	18	21
63	15	18	21	24	26
125	21	24	26	27	27
250	26	27	27	28	28
500	27	28	28	29	29
1000	28	29	29	30	33
2000	29	30	33	37	40
4000	33	37	40	44	47
8000	40	44	47	50	53

#If light-weight non-porous plaster is used, these TL values may be used for equal values of surface weight. These data must not be used for porous or so-called "acoustic plaster".

If plaster is to be used on typical stud wall construction, estimate the total thickness or weight of the plaster and use the TL values given here for that thickness, but increase the TL values where appropriate so that they are not less than those given in Table 23 for the applicable stud construction.

TABLE 29

APPROXIMATE TRANSMISSION LOSS (IN DB) OF SHEET ALUMINUM

(14 LB/SQ FT/IN. SURFACE WEIGHT)

OCTAVE FREQUENCY BAND (HZ)	THICKNESS OF ALUMINUM (IN.) 1/16	1/8	1/4
	APPROXIMATE SURFACE WEIGHT (LB/SQ FT) 1	2	3-1/2
31	0	1	7
63	1	7	13
125	7	13	19
250	13	19	23
500	19	23	25
1000	23	25	26
2000	25	26	27
4000	26	27	28
8000	27	28	32

TABLE 30

APPROXIMATE TRANSMISSION LOSS (IN DB) OF SHEET STEEL

(40 LB/SQ FT/IN. SURFACE WEIGHT)

OCTAVE FREQUENCY BAND (HZ)	THICKNESS OF STEEL (IN.) 1/16	1/8	1/4
	APPROXIMATE SURFACE WEIGHT (LB/SQ FT) 2-1/2	5	10
31	3	9	15
63	9	15	21
125	15	21	27
250	21	27	33
500	27	33	38
1000	33	38	39
2000	38	39	39
4000	39	39	37
8000	39	37	40

TABLE 31

APPROXIMATE TRANSMISSION LOSS (IN DB) OF SHEET LEAD
(60 LB/SQ FT/IN. SURFACE WEIGHT)

OCTAVE FREQUENCY BAND (HZ)	THICKNESS OF LEAD (IN.) 1/16	1/8	3/16	1/4
	APPROXIMATE SURFACE WEIGHT (LB/SQ FT) 4	7½	11	15
31	7	13	16	19
63	13	19	22	25
125	19	25	28	31
250	25	31	34	37
500	31	37	40	43
1000	37	43	46	49
2000	43	49	51	53
4000	49	53	54	55
8000	53	55	55	55

TABLE 32

APPROXIMATE WALL OR FLOOR CORRECTION TERM "C"
FOR USE IN THE EQUATION NR = TL + "C"

(Select nearest integral value of C)

RATIO S_W/R_2	"C" (dB)	RATIO S_W/R_2	"C" (dB)	RATIO S_W/R_2	"C" (dB)
0.00	+6	1.7	-3	15	-12
0.07	+5	2.2	-4	20	-13
0.15	+4	2.9	-5	25	-14
0.25	+3	3.7	-6	31	-15
0.38	+2	4.7	-7	40	-16
0.54	+1	6.1	-8	50	-17
0.75	0	7.7	-9	63	-18
1.0	-1	9.7	-10	80	-19
1.3	-2	12	-11	100	-20

S_W is the area of the wall or floor (in sq ft) common to the "transmitting" and "receiving" rooms.

R_2 is the Room Constant of the "receiving" room; include low frequency values of R_2.

TABLE 33

APPROXIMATE TRANSMISSION LOSS OF A
WALL CONTAINING DOORS OR WINDOWS

DOOR OR WINDOW AREA AS PERCENT OF TOTAL WALL AREA	IF TL OF DOOR OR WINDOW IS LESS THAN TL OF WALL BY	THEN, EFFECTIVE TL OF COMPOSITE WALL IS LESS THAN TL OF ORIGINAL WALL BY
40%	3 dB	1 dB
	6	4
	10	7
	15	11
	20	16
20%	3	1
	6	2
	10	4
	15	9
	20	13
10%	3	0
	6	1
	10	3
	15	6
	20	10
5%	3	0
	6	0
	10	1
	15	4
	20	8
2%	3	0
	6	0
	10	1
	15	2
	20	5
1%	3	0
	6	0
	10	0
	15	1
	20	3

TABLE 34

APPROXIMATE TRANSMISSION LOSS (IN DB)

OF TYPE 1 FLOOR-CEILING COMBINATION

(SEE PAGE 48 OF TEXT FOR DESCRIPTION OF TYPE 1)

OCTAVE FREQUENCY BAND (HZ)	THICKNESS OF DENSE CONCRETE SLAB (IN.) 6	8	10	12
	APPROXIMATE SURFACE WEIGHT (LB/SQ FT) 72	96	120	144
31	32	33	34	35
63	33	34	35	36
125	35	36	37	38
250	36	38	40	41
500	40	43	45	47
1000	46	50	52	54
2000	53	56	58	59
4000	58	61	63	64
8000	63	66	68	69

TABLE 35

APPROXIMATE TRANSMISSION LOSS (IN DB)

OF SOME TYPE 2 FLOOR-CEILING COMBINATIONS

(SEE PAGE 49 OF TEXT FOR DESCRIPTION OF TYPE 2)

OCTAVE FREQUENCY BAND (HZ)	THICKNESS OF DENSE CONCRETE SLAB (IN.) 6	8	10	12
	AIR SPACE BETWEEN SLAB AND SUSPENDED ACOUSTIC CEILING (IN.) 15	18	24	24
31	33	35	37	38
63	35	37	39	40
125	38	40	42	43
250	40	43	46	47
500	45	49	52	54
1000	52	57	60	62
2000	59	63	66	67
4000	64	68	71	72
8000	69	73	76	77

TABLE 36

APPROXIMATE TRANSMISSION LOSS (IN DB)

OF SOME TYPE 3 FLOOR-CEILING COMBINATIONS

(SEE PAGE 49 OF TEXT FOR DESCRIPTION OF TYPE 3)

OCTAVE FREQUENCY BAND (HZ)	THICKNESS OF DENSE CONCRETE SLAB (IN.) 6 / AIR SPACE BETWEEN SLAB AND SUSPENDED "HIGH TL" ACOUSTIC CEILING (IN.) 15	8 / 18	10 / 24	12 / 24
31	36	38	40	41
63	38	40	42	43
125	41	43	45	46
250	43	46	49	50
500	48	52	55	57
1000	55	60	63	65
2000	62	66	69	70
4000	67	71	74	75
8000	72	76	79	80

TABLE 37

APPROXIMATE TRANSMISSION LOSS (IN DB)

OF SOME TYPE 4 FLOOR-CEILING COMBINATIONS

(SEE PAGE 49 OF TEXT FOR DESCRIPTION OF TYPE 4)

OCTAVE FREQUENCY BAND (HZ)	THICKNESS OF DENSE CONCRETE SLAB (IN.) 6 / AIR SPACE BETWEEN SLAB AND RESILIENTLY SUSPENDED PLASTER CEILING (IN.) 18 / THICKNESS OF DENSE PLASTER CEILING (IN.) 1	8 / 24 / 1	10 / 30 / 1½	12 / 30 / 2
31	39	41	44	45
63	41	43	46	48
125	45	47	50	53
250	47	50	54	57
500	52	56	60	64
1000	59	64	68	72
2000	66	70	74	77
4000	71	75	78	82
8000	76	80	84	87

TABLE 38

APPROXIMATE TRANSMISSION LOSS (IN DB)

OF SOME TYPE 5 FLOOR-CEILING COMBINATIONS

(SEE PAGE 50 OF TEXT FOR DESCRIPTION OF TYPE 5)

1. FOR FLOATING FLOOR SLAB OF 3 IN. THICKNESS SUPPORTED RESILIENTLY 2 IN. ABOVE STRUCTURE SLAB: ADD 3 DB TO TABLE 37 VALUES

2. FOR FLOATING FLOOR SLAB OF 4 IN. THICKNESS SUPPORTED RESILIENTLY 2 IN. ABOVE STRUCTURE SLAB: ADD 4 DB TO TABLE 37 VALUES

3. FOR FLOATING FLOOR SLAB OF 5 IN. THICKNESS SUPPORTED RESILIENTLY 2 IN. ABOVE STRUCTURE SLAB: ADD 5 DB TO TABLE 37 VALUES

4. THE 3, 4 AND 5 DB INCREMENTS GIVEN HERE FOR 3, 4 AND 5 IN. THICK FLOATING SLABS MAY ALSO BE USED WHEN A FLOATING SLAB IS ADDED TO ANY OTHER FLOOR-CEILING COMBINATION SHOWN IN TABLES 34-36.

TABLE 39

"AREA FACTOR" ("AF") FOR USE IN DETERMINING THE PWL

OF AN AREA "A" THAT TRANSMITS SOUND LEVEL SPL

$$\text{PWL (in dB re } 10^{-12}\text{w)} = \text{SPL} + (10 \log A - 10) = \text{SPL} + \text{"AF"}$$

AREA "A" (SQ FT)	"AF" (DB)	AREA "A" (SQ FT)	"AF" (DB)	AREA "A" (SQ FT)	"AF" (DB)
1.0	-10	6.3	-2	40	6
1.25	-9	8	-1	50	7
1.6	-8	10	0	63	8
2.0	-7	12.5	1	80	9
2.5	-6	16	2	100	10
3.2	-5	20	3	125	11
4.0	-4	25	4	160	12
5.0	-3	32	5	200	13

TABLE 40

THE NATURAL FREQUENCY OF AN ISOLATOR
AS A FUNCTION OF ITS STATIC DEFLECTION
UNDER LOAD

$$F_n = 3.13\sqrt{\frac{1}{S.D.}}\ \text{Hz} = 188\sqrt{\frac{1}{S.D.}}\ \text{CPM}$$

STATIC DEFLECTION (IN.)	NATURAL FREQUENCY (Hz)	(CPM)	STATIC DEFLECTION (IN.)	NATURAL FREQUENCY (Hz)	(CPM)
0.02	22	1320	2.7	1.9	114
0.04	15.7	940	3.0	1.8	108
0.06	12.8	770	3.4	1.7	102
0.1	10	600	3.8	1.6	96
0.2	7	420	4.4	1.5	90
0.3	6.0	360	5	1.4	84
0.4	5.0	300	6	1.3	78
0.6	4.0	240	7	1.2	72
0.8	3.5	210	8	1.1	66
1.1	3.0	180	10	1.0	60
1.2	2.8	168	12	0.9	54
1.4	2.6	156	15	0.8	48
1.7	2.4	144	20	0.7	42
2.0	2.2	132	27	0.6	36
2.4	2.0	120	39	0.5	30

TABLE 41

RECOMMENDED VIBRATION ISOLATION MOUNTING DETAILS FOR RECIPROCATING-COMPRESSOR REFRIGERATION EQUIPMENT ASSEMBLY (INCLUDING MOTOR, GEAR OR STEAM TURBINE DRIVE UNIT)

EQUIPMENT CONDITIONS			MOUNTING RECOMMENDATIONS				
EQUIPMENT LOCATION	COOLING CAPACITY (TONS)	SPEED RANGE (RPM)	COLUMN 1	COLUMN 2	COLUMN 3		
					30'	40'	50'
ON GRADE SLAB	10-50	600-900	III			2"	
		901-1200	III			1½"	
		1201-2400	III			1"	
	51-175	600-900	II	2-3		2"	
		901-1200	III			2"	
		1201-2400	III			1½"	
ON UPPER FLOOR ABOVE NON-CRITICAL AREA	10-50	600-900	II	2-3	2"	3"	4"
		901-1200	II	2-3	1½"	2"	3"
		1201-2400	II	2-3	1½"	1½"	2"
	51-175	600-900	II	3-4	3"	4"	5"
		901-1200	II	3-4	2"	3"	4"
		1201-2400	II	2-3	2"	2"	3"
ON UPPER FLOOR ABOVE CRITICAL AREA	10-50	600-900	II	3-4	3"	4"	5"
		901-1200	II	3-4	2"	3"	4"
		1201-2400	II	2-3	2"	2"	3"
	51-175	600-900	I	4-6	3"	4"	5"
		901-1200	II	3-5	2"	3"	4"
		1201-2400	II	3-4	2"	2"	3"

COL 1: MOUNTING TYPE (SEE TEXT)
COL 2: MINIMUM RATIO OF WEIGHT OF INERTIA BLOCK TO TOTAL WEIGHT OF SUPPORTED LOAD
COL 3: MINIMUM STATIC DEFLECTION OF STABLE STEEL SPRINGS IN INCHES FOR INDICATED FLOOR SPAN IN FEET

TABLE 42

RECOMMENDED VIBRATION ISOLATION MOUNTING DETAILS FOR ROTARY-SCREW-COMPRESSOR REFRIGERATION EQUIPMENT ASSEMBLY (INCLUDING MOTOR DRIVE UNIT)

EQUIPMENT CONDITIONS			MOUNTING RECOMMENDATIONS				
EQUIPMENT LOCATION	COOLING CAPACITY (TONS)	SPEED RANGE (RPM)	COLUMN 1	COLUMN 2	COLUMN 3		
					30'	40'	50'
ON GRADE SLAB	100-500	2400-4800	III		1"		
ON UPPER FLOOR ABOVE NON-CRITICAL AREA	100-500	2400-4800	III		1"	1½"	2"
ON UPPER FLOOR ABOVE CRITICAL AREA	100-500	2400-4800	II	2-3	1"	1½"	2"

COL 1: MOUNTING TYPE (SEE TEXT)
COL 2: MINIMUM RATIO OF WEIGHT OF INERTIA BLOCK TO TOTAL WEIGHT OF SUPPORTED LOAD
COL 3: MINIMUM STATIC DEFLECTION OF STABLE STEEL SPRINGS IN INCHES FOR INDICATED FLOOR SPAN IN FEET

TABLE 43

RECOMMENDED VIBRATION ISOLATION MOUNTING DETAILS FOR CENTRIFUGAL-COMPRESSOR REFRIGERATION EQUIPMENT ASSEMBLY (INCLUDING CONDENSER AND CHILLER TANKS AND MOTOR, GEAR OR STEAM TURBINE DRIVE UNIT)

EQUIPMENT CONDITIONS			MOUNTING RECOMMENDATIONS				
EQUIPMENT LOCATION	COOLING CAPACITY (TONS)	SPEED RANGE (RPM)	COLUMN 1	COLUMN 2	COLUMN 3 30'	40'	50'
ON GRADE SLAB	100-500	OVER 3000	III		3/4"		
	501-4000	OVER 3000	III		1"		
ON UPPER FLOOR ABOVE NON-CRITICAL AREA	100-500	OVER 3000	III		1"	1½"	2"
	501-4000 PACKAGED	OVER 3000	III		1½"	2"	3"
	501-4000 BUILT-UP	OVER 3000	II	2-3	1½"	2"	3"
ON UPPER FLOOR ABOVE CRITICAL AREA	100-500	OVER 3000	II	2-3	1½"	2"	3"
	501-4000	OVER 3000	II	3-5	1½"	2"	3"

COL 1: MOUNTING TYPE (SEE TEXT)

COL 2: MINIMUM RATIO OF WEIGHT OF INERTIA BLOCK TO TOTAL WEIGHT OF SUPPORTED LOAD

COL 3: MINIMUM STATIC DEFLECTION OF STABLE STEEL SPRINGS IN INCHES FOR INDICATED FLOOR SPAN IN FEET

TABLE 44

RECOMMENDED VIBRATION ISOLATION MOUNTING DETAILS FOR ABSORPTION-TYPE REFRIGERATION EQUIPMENT ASSEMBLY

<table>
<tr><th colspan="3">EQUIPMENT CONDITIONS</th><th colspan="5">MOUNTING RECOMMENDATIONS</th></tr>
<tr><th rowspan="2">EQUIPMENT LOCATION</th><th rowspan="2">COOLING CAPACITY (TONS)</th><th rowspan="2">SPEED RANGE (RPM)</th><th rowspan="2">COLUMN 1</th><th rowspan="2">COLUMN 2</th><th colspan="3">COLUMN 3</th></tr>
<tr><th>30'</th><th>40'</th><th>50'</th></tr>
<tr><td rowspan="3">ON GRADE SLAB</td><td>ALL SIZES</td><td></td><td>IV</td><td></td><td colspan="3">¾"</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="3"></td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="3"></td></tr>
<tr><td rowspan="3">ON UPPER FLOOR ABOVE NON-CRITICAL AREA</td><td>ALL SIZES</td><td></td><td>III</td><td></td><td>½"</td><td>3/4"</td><td>1"</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">ON UPPER FLOOR ABOVE CRITICAL AREA</td><td>ALL SIZES</td><td></td><td>III</td><td></td><td>1"</td><td>1½"</td><td>2"</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

COL 1: MOUNTING TYPE (SEE TEXT)
COL 2: MINIMUM RATIO OF WEIGHT OF INERTIA BLOCK TO TOTAL WEIGHT OF SUPPORTED LOAD
COL 3: MINIMUM STATIC DEFLECTION OF ISOLATORS IN INCHES FOR INDICATED FLOOR SPAN IN FEET

TABLE 45

RECOMMENDED VIBRATION ISOLATION MOUNTING DETAILS FOR BOILERS

EQUIPMENT CONDITIONS			MOUNTING RECOMMENDATIONS				
EQUIPMENT LOCATION	HEATING CAPACITY (BHP)	SPEED RANGE (RPM)	COLUMN 1	COLUMN 2	COLUMN 3		
					30'	40'	50'
ON GRADE SLAB	UNDER 200		---		NOT REQUIRED		
	200-1000		IV		1/8"		
	OVER 1000		IV		1/4"		
ON UPPER FLOOR ABOVE NON-CRITICAL AREA	UNDER 200		III		1/8"	¼"	½"
	200-1000		III		¼"	½"	1"
	OVER 1000		III		¼"	½"	1"
ON UPPER FLOOR ABOVE CRITICAL AREA	UNDER 200		III		½"	1"	1½"
	200-1000		III		1"	1½"	2"
	OVER 1000		III		1"	1½"	2"

COL 1: MOUNTING TYPE (SEE TEXT)
COL 2: MINIMUM RATIO OF WEIGHT OF INERTIA BLOCK TO TOTAL WEIGHT OF SUPPORTED LOAD
COL 3: MINIMUM STATIC DEFLECTION OF ISOLATORS IN INCHES FOR INDICATED FLOOR SPAN IN FEET

TABLE 46

RECOMMENDED VIBRATION ISOLATION MOUNTING DETAILS FOR
PROPELLER-TYPE COOLING TOWERS
(WHERE SEVERAL TOWERS ARE PLACED AT THE SAME GENERAL LOCATION,
USE POWER RANGE FOR TOTAL POWER OF ALL TOWERS)

EQUIPMENT CONDITIONS			MOUNTING RECOMMENDATIONS				
EQUIPMENT LOCATION	POWER RANGE (HP)	FAN SPEED (RPM)	COLUMN 1	COLUMN 2	COLUMN 3		
					30'	40'	50'
ON GRADE SLAB	VIBRATION ISOLATION USUALLY NOT REQUIRED						
ON UPPER FLOOR ABOVE NON-CRITICAL AREA	UNDER 25	150-300 301-600 OVER 600	V	INSTALL ON	5" 3" 3"	SPRINGS MAY BE LOCATED	
	25-150	150-300 301-600 OVER 600	V	DUNNAGE ATTACHED TO	6" 4" 3"	UNDER DRIVE ASSEMBLY	
	OVER 150	150-300 301-600 OVER 600	V	BUILDING COLUMNS ONLY	6" 5" 4"	OR UNDER TOWER BASE	
ON UPPER FLOOR ABOVE CRITICAL AREA	SAME AS FOR LOCATION ABOVE NON-CRITICAL AREA, EXCEPT INSTALL RIBBED OR WAFFLE-PATTERN NEOPRENE BETWEEN TOWER AND BUILDING.						

COL 1: MOUNTING TYPE (SEE TEXT)
COL 2: MINIMUM RATIO OF WEIGHT OF INERTIA BLOCK TO TOTAL WEIGHT OF SUPPORTED LOAD
COL 3: MINIMUM STATIC DEFLECTION OF STABLE STEEL SPRINGS IN INCHES FOR INDICATED FLOOR SPAN IN FEET

TABLE 47

RECOMMENDED VIBRATION ISOLATION MOUNTING DETAILS FOR
CENTRIFUGAL-TYPE COOLING TOWERS
(POWER IS TOTAL OF ALL FANS AT THE SAME GENERAL LOCATION)

EQUIPMENT CONDITIONS			MOUNTING RECOMMENDATIONS				
EQUIPMENT LOCATION	POWER RANGE (HP)	FAN SPEED (RPM)	COLUMN 1	COLUMN 2	COLUMN 3 30'	40'	50'
ON GRADE SLAB	VIBRATION ISOLATION USUALLY NOT REQUIRED						
ON UPPER FLOOR ABOVE NON-CRITICAL AREA	UNDER 25	450-900	III		1"	1½"	2"
		901-1800			3/4"	1"	1½"
		OVER 1800			3/4"	1"	1½"
	25-150	450-900	III		1½"	2"	3"
		901-1800			1"	1½"	2"
		OVER 1800			3/4"	1"	1½"
	OVER 150	450-900	III		2"	3"	4"
		901-1800			1½"	2"	3"
		OVER 1800			1"	1½"	2"
ON UPPER FLOOR ABOVE CRITICAL AREA	UNDER 25	450-900	III		1½"	2"	3"
		901-1800			1"	1½"	2"
		OVER 1800			3/4"	1"	1½"
	25-150	450-900	III		2"	3"	4"
		901-1800			1½"	2"	3"
		OVER 1800			1"	1½"	2"
	OVER 150	450-900	III		3"	4"	6"
		901-1800			1½"	2"	3"
		OVER 1800			1"	1½"	2"

COL 1: MOUNTING TYPE (SEE TEXT)
COL 2: MINIMUM RATIO OF WEIGHT OF INERTIA BLOCK TO TOTAL WEIGHT OF SUPPORTED LOAD
COL 3: MINIMUM STATIC DEFLECTION OF STABLE STEEL SPRINGS IN INCHES FOR INDICATED FLOOR SPAN IN FEET

TABLE 48

RECOMMENDED VIBRATION ISOLATION MOUNTING DETAILS FOR MOTOR-PUMP ASSEMBLIES

EQUIPMENT CONDITIONS			MOUNTING RECOMMENDATIONS				
EQUIPMENT LOCATION	POWER RANGE (HP)	SPEED RANGE (RPM)	COLUMN 1	COLUMN 2	COLUMN 3 30'	COLUMN 3 40'	COLUMN 3 50'
ON GRADE SLAB	UNDER 20	450-900	II	1½-2½	1½"		
		901-1800	II OR III	2±	1½"		
		1801-3600	II OR III	2±	1"		
	20-100	450-900	II	2-3	1½"		
		901-1800	II	1½-2½	1"		
		1801-3600	II	1½-2½	3/4"		
	OVER 100	450-900	II	2-3	2"		
		901-1800	II	2-3	1½"		
		1801-3600	II	1½-2½	1"		
ON UPPER FLOOR ABOVE NON-CRITICAL AREA	UNDER 20	450-900	II	2-3	1½"	2"	3"
		901-1800	II	1½-2½	1"	1½"	2"
		1801-3600	II	1½-2½	3/4"	1"	1½"
	20-100	450-900	II	2-3	1½"	2"	3"
		901-1800	II	2-3	1"	1½"	2"
		1801-3600	II	1½-2½	1"	1½"	2"
	OVER 100	450-900	II	3-4	2"	3"	4"
		901-1800	II	2-3	1½"	2"	3"
		1801-3600	II	2-3	1"	1½"	2"
ON UPPER FLOOR ABOVE CRITICAL AREA	UNDER 20	450-900	II	3-4	1½"	2"	3"
		901-1800	II	2-3	1"	1½"	2"
		1801-3600	II	2-3	3/4"	1"	1½"
	20-100	450-900	II	3-4	2"	3"	4"
		901-1800	II	2-3	1½"	2"	3"
		1801-3600	II	2-3	1"	1½"	2"
	OVER 100	450-900	II	3-4	3"	4"	5"
		901-1800	II	2-3	2"	3"	4"
		1801-3600	II	2-3	1½"	2"	3"

COL 1: MOUNTING TYPE (SEE TEXT)
COL 2: MINIMUM RATIO OF WEIGHT OF INERTIA BLOCK TO TOTAL WEIGHT OF SUPPORTED LOAD
COL 3: MINIMUM STATIC DEFLECTION OF STABLE STEEL SPRINGS IN INCHES FOR INDICATED FLOOR SPAN IN FEET

TABLE 49

RECOMMENDED VIBRATION ISOLATION MOUNTING DETAILS FOR
STEAM-TURBINE-DRIVEN ROTARY EQUIPMENT,
SUCH AS GEAR, GENERATOR OR GAS COMPRESSOR
(USE TABLE 41 FOR RECIP. COMPR. DRIVEN BY STEAM TURBINE;
USE TABLE 43 FOR CENTR. COMPR. DRIVEN BY STEAM TURBINE)

EQUIPMENT CONDITIONS			MOUNTING RECOMMENDATIONS				
EQUIPMENT LOCATION	POWER RANGE (HP)	SPEED RANGE (RPM)	COLUMN 1	COLUMN 2	COLUMN 3		
					30'	40'	50'
ON GRADE SLAB	500-1500	OVER 3000	III		1"		
	1501-5000	OVER 3000	III		1½"		
	5001-15000	OVER 3000	III		2"		
ON UPPER FLOOR ABOVE NON-CRITICAL AREA	500-1500	OVER 3000	II	2-3	1"	1½"	2"
	1501-5000	OVER 3000	II	2-3	1½"	2"	3"
	5001-15000	OVER 3000	II	2-3	2"	3"	4"
ON UPPER FLOOR ABOVE CRITICAL AREA	500-1500	OVER 3000	II	3-5	1"	1½"	2"
	1501-5000	OVER 3000	II	3-5	1½"	2"	3"
	5001-15000	OVER 3000	II	3-5	2"	3"	4"

COL 1: MOUNTING TYPE (SEE TEXT)
COL 2: MINIMUM RATIO OF WEIGHT OF INERTIA BLOCK TO TOTAL WEIGHT OF SUPPORTED LOAD
COL 3: MINIMUM STATIC DEFLECTION OF STABLE STEEL SPRINGS IN INCHES FOR INDICATED FLOOR SPAN IN FEET

TABLE 50

RECOMMENDED VIBRATION ISOLATION MOUNTING DETAILS FOR TRANSFORMERS

EQUIPMENT CONDITIONS			MOUNTING RECOMMENDATIONS				
EQUIPMENT LOCATION	POWER RANGE (KVA)	SPEED RANGE (RPM)	COLUMN 1	COLUMN 2	COLUMN 3		
					30'	40'	50'
ON GRADE SLAB	UNDER 10		IV		1/8"		
	10-100		IV		1/8"		
	OVER 100		IV		1/4"		
ON UPPER FLOOR ABOVE NON-CRITICAL AREA	UNDER 10		IV		1/8"	¼"	¼"
	10-100		III		¼"	½"	½"
	OVER 100		III		¼"	½"	1"
ON UPPER FLOOR ABOVE CRITICAL AREA	UNDER 10		III		¼"	½"	3/4"
	10-100		III		½"	3/4"	1"
	OVER 100		III		½"	1"	1½"

COL 1: MOUNTING TYPE (SEE TEXT)
COL 2: MINIMUM RATIO OF WEIGHT OF INERTIA BLOCK TO TOTAL WEIGHT OF SUPPORTED LOAD
COL 3: MINIMUM STATIC DEFLECTION OF ISOLATORS IN INCHES FOR INDICATED FLOOR SPAN IN FEET

TABLE 51

RECOMMENDED VIBRATION ISOLATION MOUNTING DETAILS FOR

ONE- OR TWO-CYLINDER RECIPROCATING-TYPE AIR COMPRESSORS

IN THE 10-100 HP SIZE RANGE

<table>
<tr><th colspan="3">EQUIPMENT CONDITIONS</th><th colspan="5">MOUNTING RECOMMENDATIONS</th></tr>
<tr><th rowspan="2">EQUIPMENT LOCATION</th><th rowspan="2">POWER RANGE (HP)</th><th rowspan="2">SPEED RANGE (RPM)</th><th rowspan="2">COLUMN 1</th><th rowspan="2">COLUMN 2</th><th colspan="3">COLUMN 3</th></tr>
<tr><th>30'</th><th>40'</th><th>50'</th></tr>
<tr><td rowspan="6">ON GRADE SLAB</td><td rowspan="3">UNDER 20</td><td>300-600</td><td>I</td><td>4-8</td><td colspan="3">4"</td></tr>
<tr><td>601-1200</td><td>I</td><td>2-4</td><td colspan="3">2"</td></tr>
<tr><td>1201-2400</td><td>I</td><td>1-2</td><td colspan="3">1"</td></tr>
<tr><td rowspan="3">20-100</td><td>300-600</td><td>I</td><td>6-10</td><td colspan="3">5"</td></tr>
<tr><td>601-1200</td><td>I</td><td>3-6</td><td colspan="3">3"</td></tr>
<tr><td>1201-2400</td><td>I</td><td>2-3</td><td colspan="3">1½"</td></tr>
<tr><td rowspan="6">ON UPPER FLOOR ABOVE NON-CRITICAL AREA</td><td rowspan="3">UNDER 20</td><td>300-600</td><td colspan="3">NOT RECOMMENDED</td><td></td><td></td></tr>
<tr><td>601-1200</td><td>I</td><td>3-6</td><td>4"</td><td>NO#</td><td>NO#</td></tr>
<tr><td>1201-2400</td><td>I</td><td>2-3</td><td>2"</td><td>4"</td><td>NO#</td></tr>
<tr><td rowspan="3">20-100</td><td>300-600</td><td colspan="3">NOT RECOMMENDED</td><td></td><td></td></tr>
<tr><td>601-1200</td><td colspan="3">NOT RECOMMENDED</td><td></td><td></td></tr>
<tr><td>1201-2400</td><td>I</td><td>3-6</td><td>3"</td><td>6"</td><td>NO#</td></tr>
<tr><td rowspan="4">ON UPPER FLOOR ABOVE CRITICAL AREA</td><td rowspan="3">UNDER 20</td><td>300-600</td><td colspan="3">NOT RECOMMENDED</td><td></td><td></td></tr>
<tr><td>601-1200</td><td colspan="3">NOT RECOMMENDED</td><td></td><td></td></tr>
<tr><td>1201-2400</td><td>I</td><td>3-6</td><td>4"</td><td>NO#</td><td>NO#</td></tr>
<tr><td>20-100</td><td>300-2400</td><td colspan="3">NOT RECOMMENDED</td><td></td><td></td></tr>
</table>

COL 1: MOUNTING TYPE (SEE TEXT)
COL 2: MINIMUM RATIO OF WEIGHT OF INERTIA BLOCK TO TOTAL WEIGHT OF SUPPORTED LOAD
COL 3: MINIMUM STATIC DEFLECTION OF STABLE STEEL SPRINGS IN INCHES FOR INDICATED FLOOR SPAN IN FEET

\# "NO" INDICATES "NOT RECOMMENDED" FOR THIS COMBINATION OF CONDITIONS

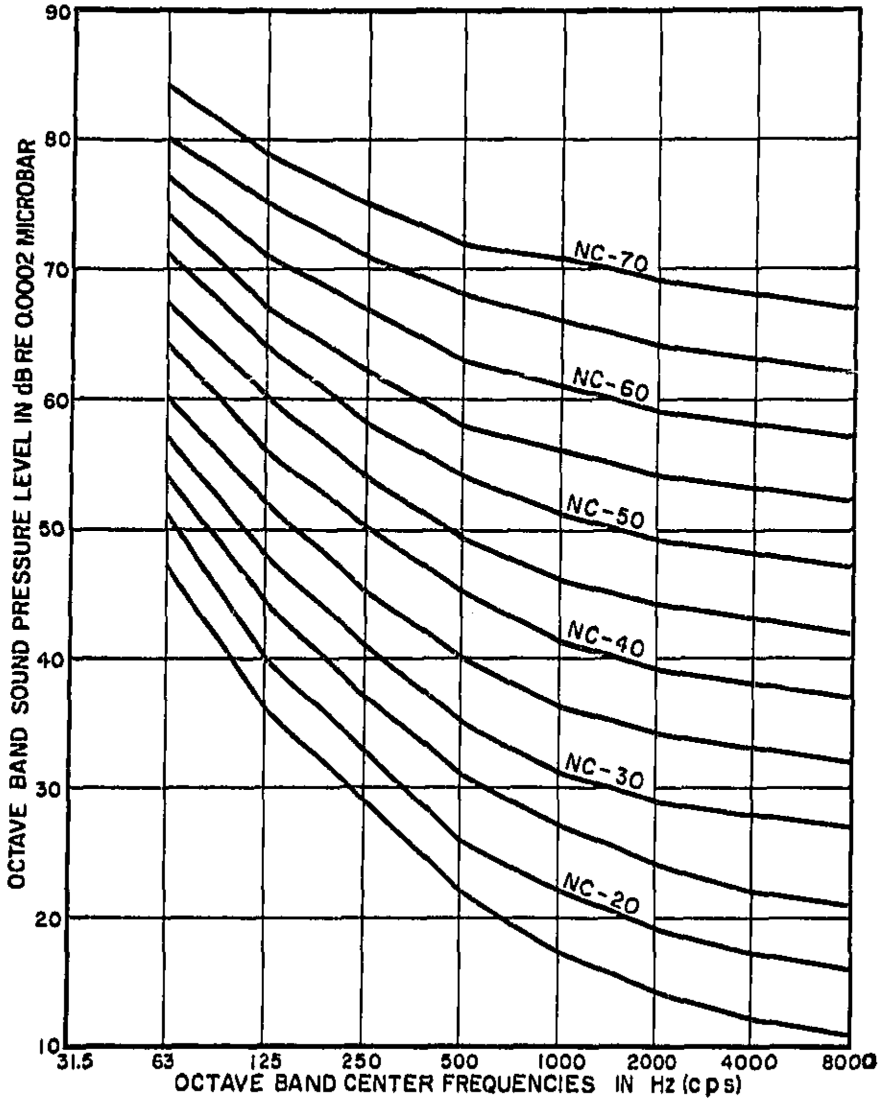


FIG. 1 INDOOR NOISE CRITERION "NC" CURVES. REFER TO TABLE 1 FOR NUMERICAL VALUES OF SOUND PRESSURE LEVELS OF NC CURVES. REFER TO TABLE 2 FOR APPLICABLE AREAS.

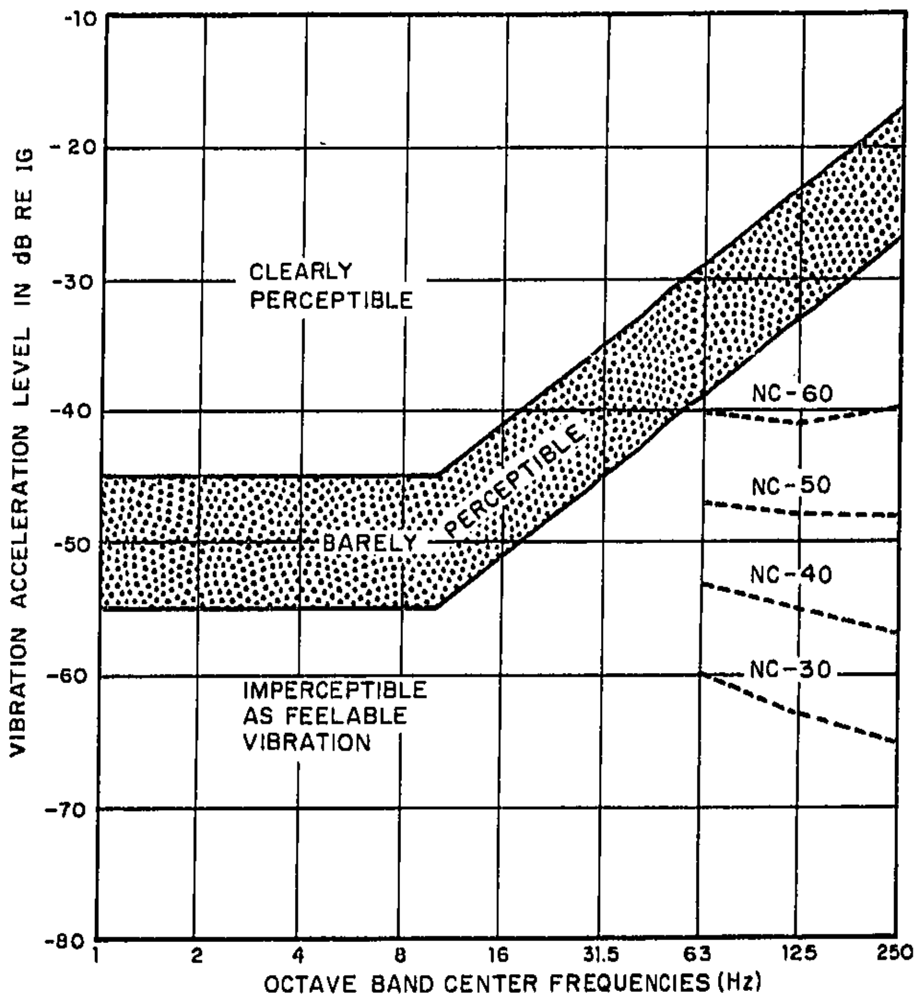


FIG. 2 VIBRATION ACCELERATION LEVELS NEAR THE ONSET OF "FEELABILITY"

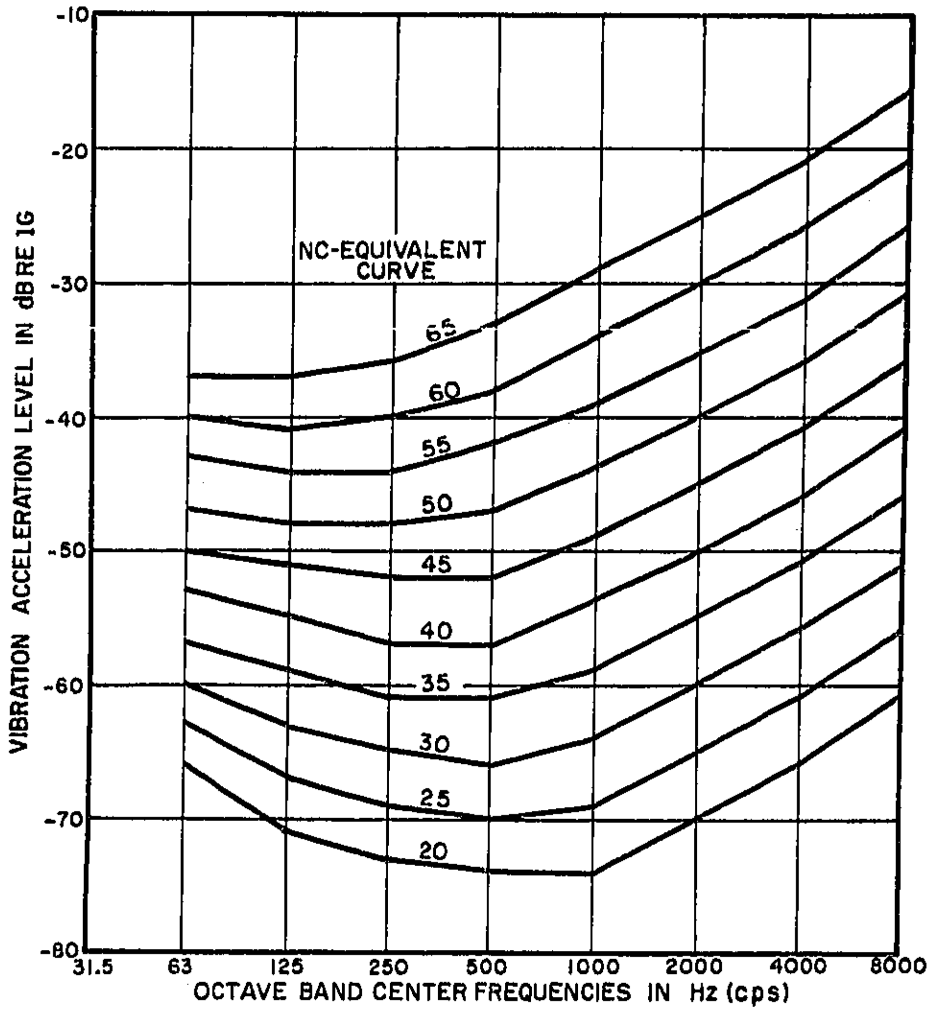


FIG. 3 ACCELERATION LEVELS OF A LARGE VIBRATING SURFACE THAT WILL PRODUCE RADIATED SOUND LEVELS INTO A ROOM APPROXIMATING THE SOUND LEVELS OF THE NC CURVES.

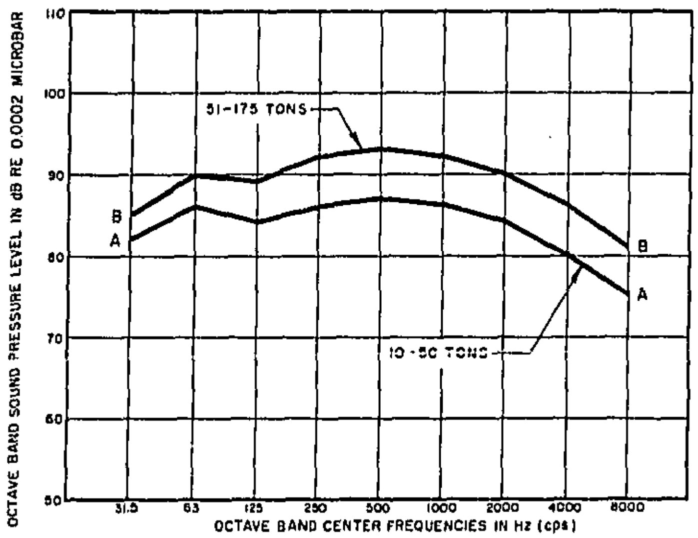


FIG.4 NOISE LEVELS OF RECIPROCATING COMPRESSORS AT 3-FT DISTANCE
(Suggested design curves for two ranges of cooling capacity)

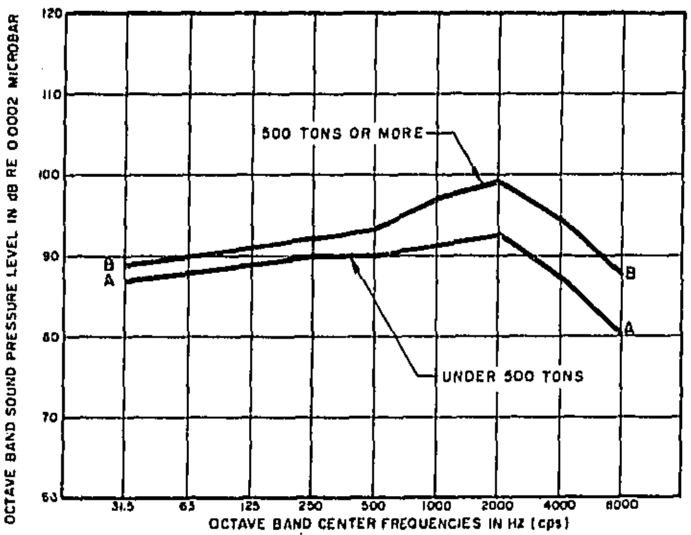


FIG.5 NOISE LEVELS OF CENTRIFUGAL COMPRESSORS AT 3-ft DISTANCE
(Suggested design curves for two ranges of cooling capacity)

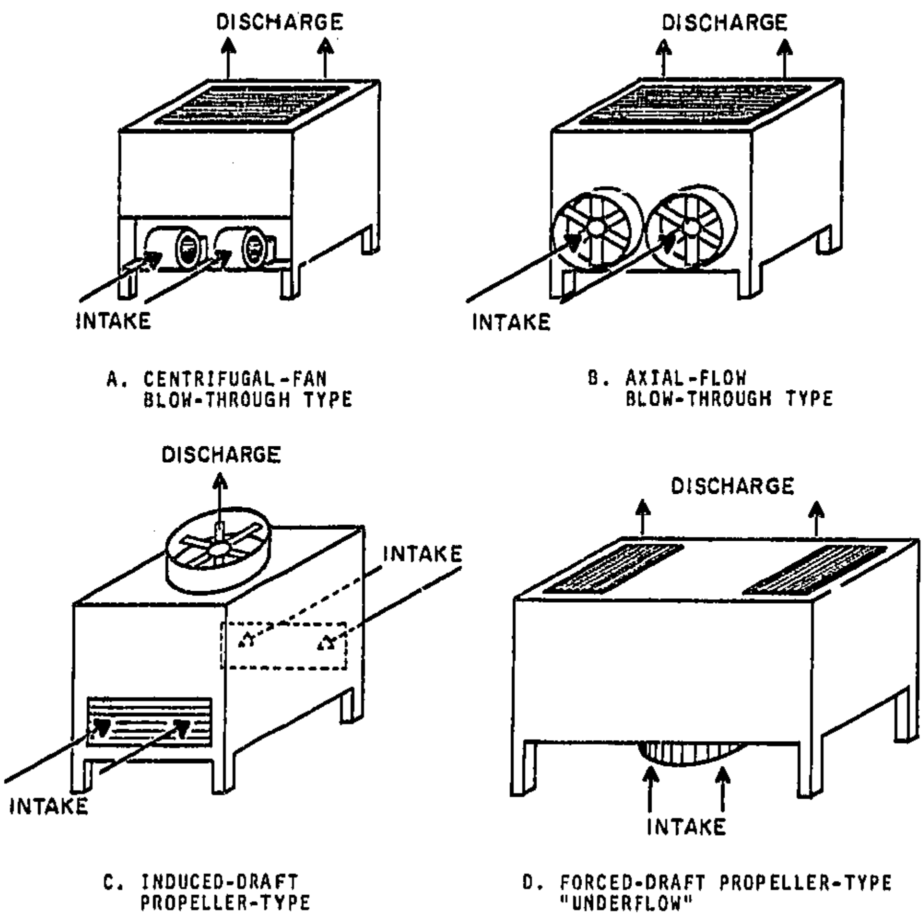


FIG. 6 PRINCIPAL TYPES OF COOLING TOWERS

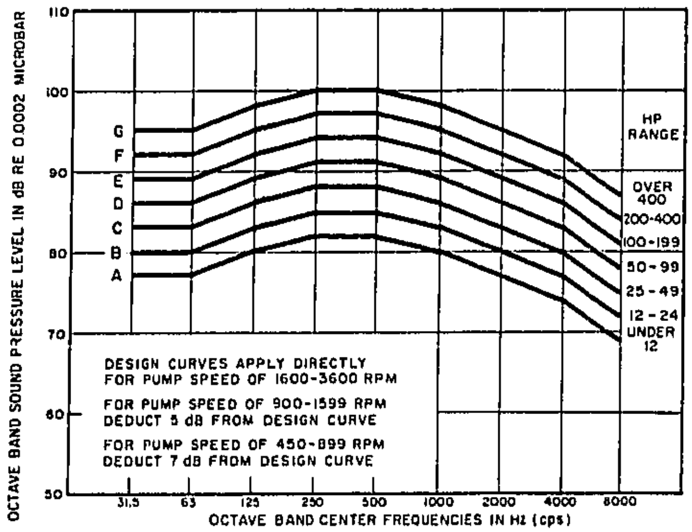


FIG.7 PUMP NOISE LEVELS AT 3-ft DISTANCE
(Suggested design curves for various powers and speeds)

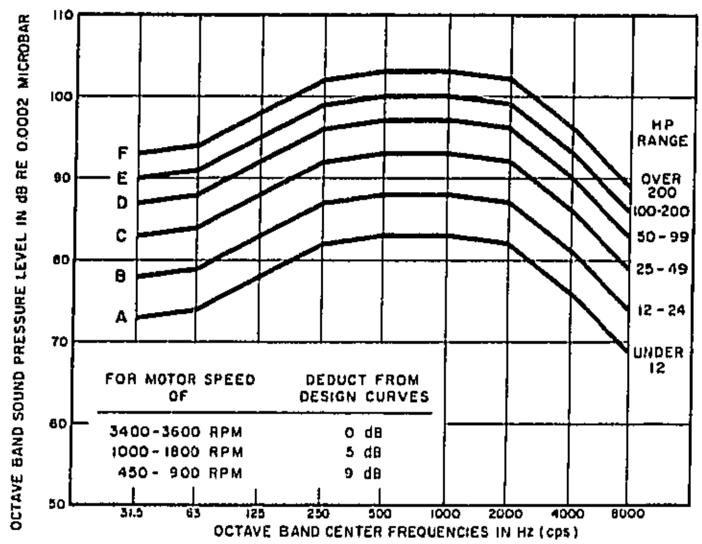


FIG.8 NOISE LEVELS OF ELECTRIC MOTORS AT 3-ft DISTANCE (SUGGESTED DESIGN CURVES FOR VARIOUS POWER AND SPEED RANGES)

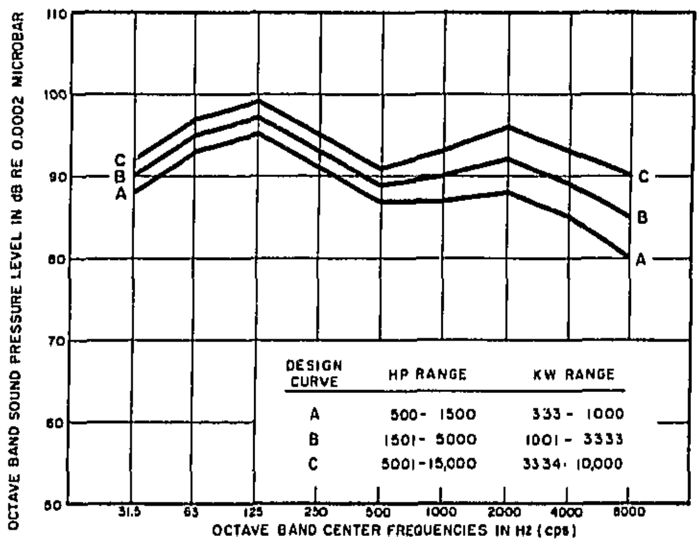


FIG.9 STEAM TURBINE NOISE LEVELS AT 3-FT DISTANCE
(Suggested Design Curves for Various Power Ranges)

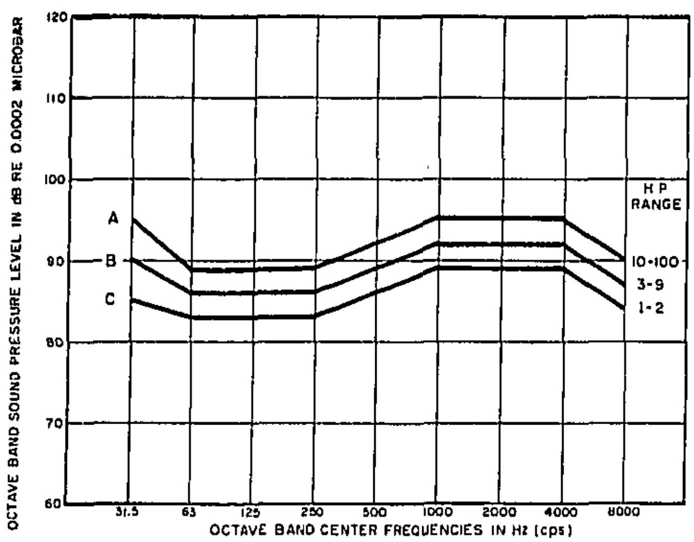


FIG.10 NOISE LEVELS 3 FT FROM AIR COMPRESSORS
(Suggested design curves for either reciprocating or centrifugal type in power range of 1-100 HP)

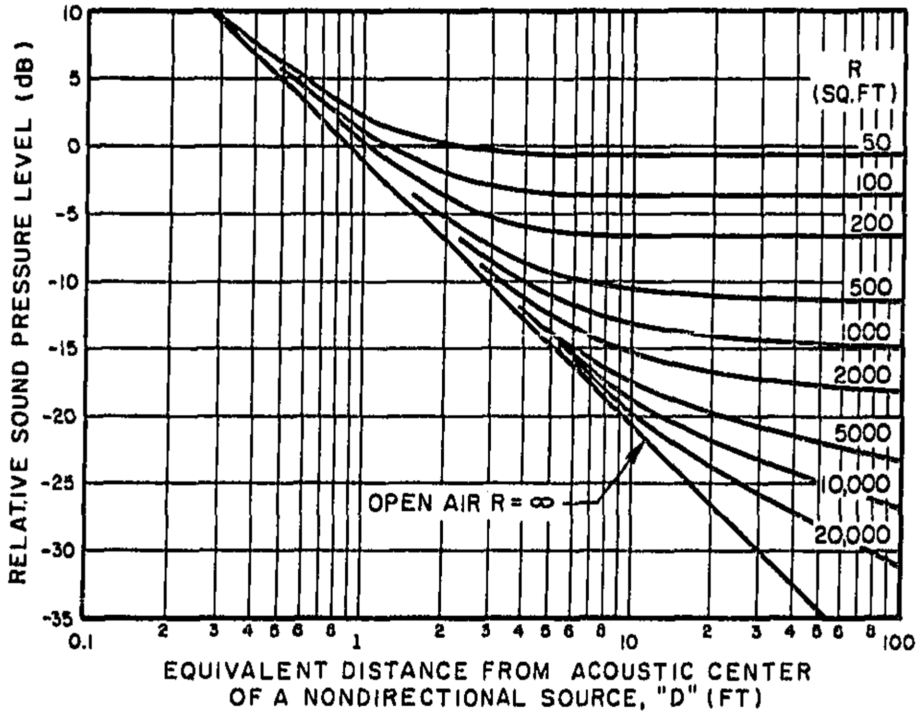


FIG.11 APPROXIMATE RELATIONSHIP BETWEEN "RELATIVE SOUND PRESSURE LEVEL" AND DISTANCE TO A NOISE SOURCE FOR VARIOUS ROOM CONSTANT VALUES

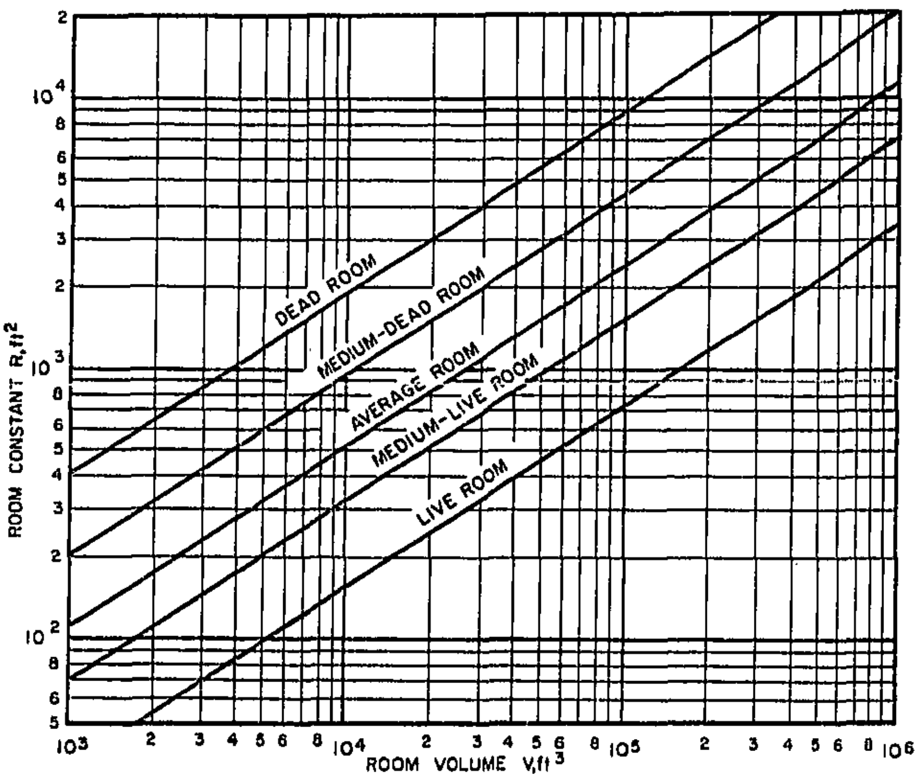


FIG.12 APPROXIMATE RELATIONSHIP BETWEEN ROOM VOLUME AND ROOM CONSTANT FOR SPACES OF VARIOUS AVERAGE ACOUSTIC ABSORPTION (AT MID-FREQUENCY REGION OF 500-1000 Hz)

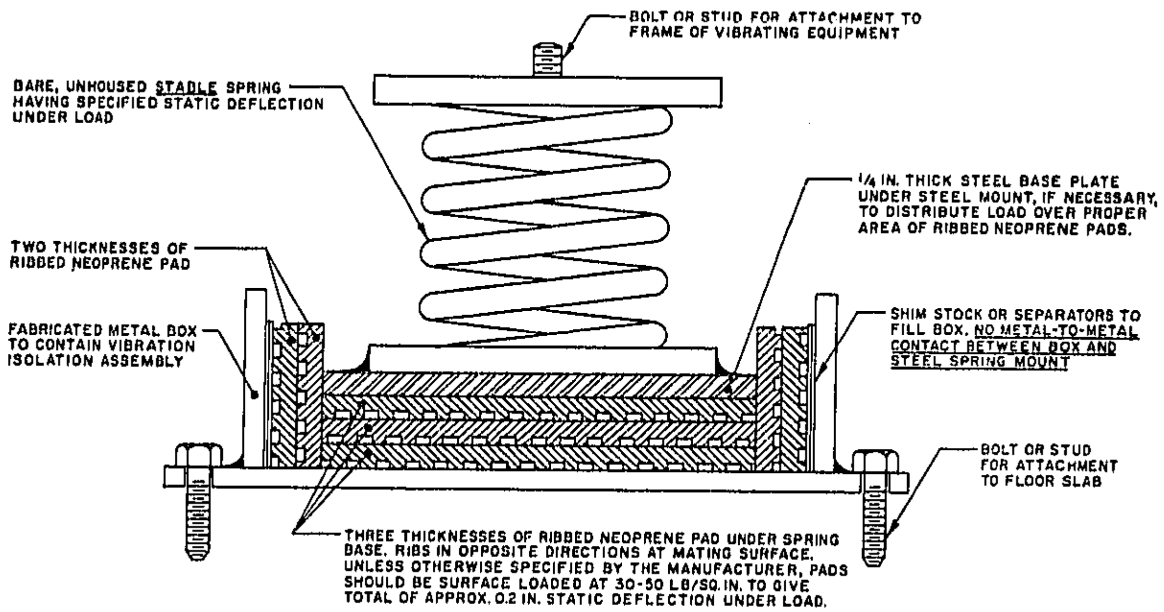


FIG. 13 DETAIL OF VIBRATION ISOLATION MOUNT USING STEEL SPRING AND RIBBED-NEOPRENE PADS

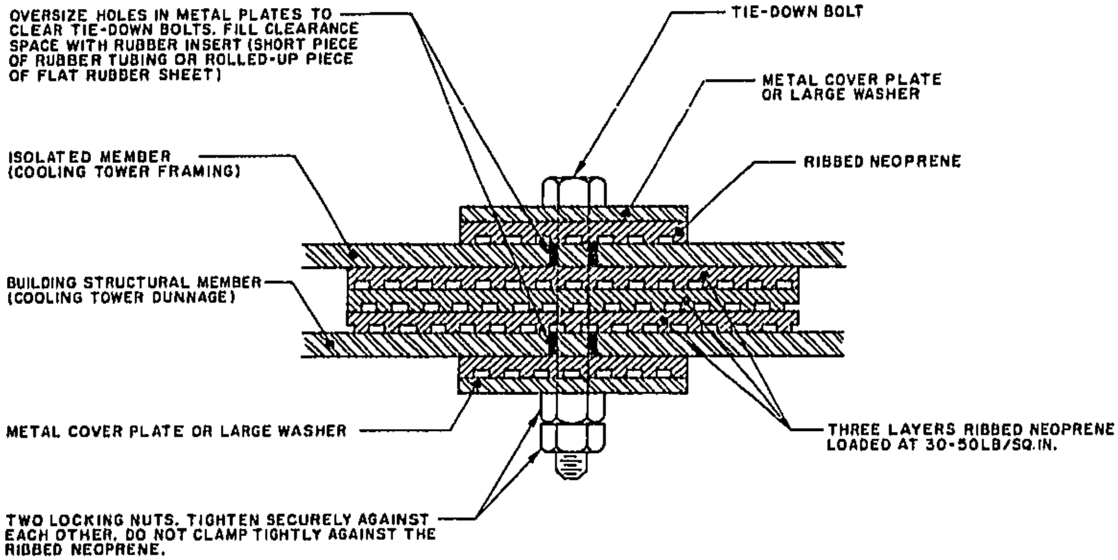


FIG. 14 DETAIL OF TIE-DOWN BOLT USED WITH COOLING TOWER ISOLATION PADS

By Order of the Secretary of the Army:

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Chief of Staff.

Official:

KENNETH G. WICKHAM,
Major General, United States Army,
The Adjutant General.