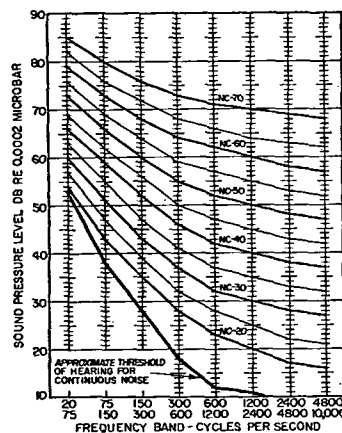




Each NC curve has a loudness level in phons that is 22 units greater than the Speech Interference Level in decibels (expressed by the NC number of the curve). These curves should be used in design or specifications wherever a favorable relation between the low frequency and the high frequency portion of the spectrum is desired (see text).

Fig. 3 . . . Criterion Curves for Use with Table 1 in Determining the Permissible (or Desirable)  $L_p$  Values in 8 Octave Frequency Bands

such cases it is advisable to make an octave band analysis of the noise, if possible.

#### KINDS OF NOISE

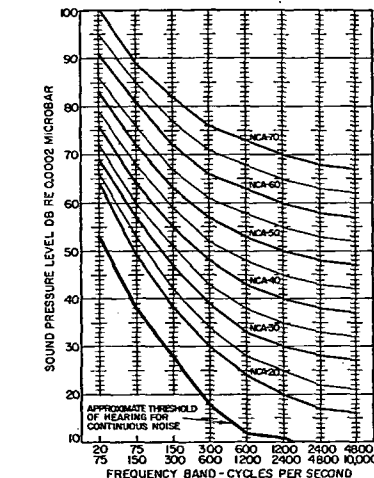
The noise introduced into a room or building by ventilating or air-conditioning equipment may be divided into two general kinds, depending on how it reaches the room:

1. *Noise transmitted through the ducts.*
  - a. From equipment such as fans, motors, sprays, etc.
  - b. From outside, and transmitted through duct walls into air stream.
  - c. From duct wall vibrations, transmitted into air stream.
  - d. From air currents, including eddying noises.
  - e. Cross talk and cross noises between rooms connected by the same duct system.
  - f. From dampers and air valves located near branch duct take-offs and outlets.
- g. *Noise produced by grilles or diffusers.*
2. *Noise transmitted through the building construction.*
  - a. From machine mountings as vibration.
  - b. From equipment through room wall surfaces.

The following text will present data and discussion of methods whereby solutions of the noise problem can be obtained when the allowable room noise level, and the path through which the noise reaches the room, are known.

#### NOISE GENERATED BY FANS

Aerodynamic noise from all types of fans may be broadly divided into a rotational component and a vortex component.



Same as Fig. 3 except that each NCA curve has a loudness level in phons that is 30 units greater than the Speech Interference Level in decibels (expressed by the NCA number of the curve). These curves may be used in design or specifications in place of those of Fig. 3 wherever economy dictates a maximum compromise and where, in addition, the fan and turbulence noise is steady and free of low frequency pure tone components (see text).

Fig. 4 . . . Criterion Curves for Use with Table 1 in Determining the Permissible (or Desirable)  $L_p$  Values in 8 Octave Frequency Bands

The rotational component is associated with the impulse given to the air each time a blade passes a given point and is hence a series of discrete tones at the fundamental blade passing frequency and harmonics thereof. The vortex component of noise is largely due to the shedding of vortices from the fan blades. It is random in character and has a continuous spectrum over a wide range of frequencies determined by the fan geometry and operation. It may also have many nonharmonic single-frequency components determined by blade geometry and local air velocity. Since the laws of generation of these two types of noise are different, they will vary in importance for different types of fans and operating conditions.<sup>7, 8</sup>

In addition to aerodynamic noise, there are usually several non-aerodynamic sources of noise in equipment involving fans. Such sources include noise resulting from unbalance, bearing noise, brush noise, magnetic noise, and belt noise.

The number of blades of a centrifugal fan generally is governed by optimum air-flow design. The noise generation decreases but slightly for more than the optimum number of blades.

Powerful tones of definite pitch may be generated in fans when the wakes from the impeller blades impinge on an obstruction such as a badly located or shaped cut-off in a centrifugal fan, or struts or motor supports which are badly shaped and too close to the impeller of an axial flow or propeller fan.

#### Sound Control

This interference noise has the same frequency characteristics as rotation noise.<sup>9</sup>

A shroud around a propeller fan may serve to reduce noise considerably if it is working properly. Such reduction is generally most effective at the higher harmonics. However, if the flow breaks down over part of the shroud, the noise may become considerably worse than for an unshrouded case.

As the operating pressure across axial fans is increased the maximum sound intensity is shifted from the fundamental to higher harmonics. This effect is not observed for centrifugal fans.

#### Effect of Fan Parameters on Noise vs. Performance

**Fan Laws.** The principal laws governing the mechanical performance of a fan, whether centrifugal or axial, are fairly well established and are given in Chapter 22.

**Fixed Point of Rating.** A fixed point of rating of a given size fan at a given speed is one for which the capacity (volume flow) is chosen as a given fraction of the free delivery capacity. Having chosen this capacity ratio, the ratio of pressure to the static no-delivery pressure is determined. This fixed point of rating will have a fixed efficiency within the limitation of certain manufacturing details. The fan laws serve to relate the performance of two members of a symmetrical series of fans operating at the same fixed point of rating whether at the same or different speeds.

**Correlation of Fan Noise with Size, Static Pressure, Speed, and Capacity.** The empirical relations between the noise generated by a fan and its size, static pressure, speed, and capacity are as follows:

Change in overall sound power level varies as:

$$70 \log_{10}(\text{size}_2/\text{size}_1) + 50 \log_{10}(\text{speed}_2/\text{speed}_1) \quad (12)$$

$$20 \log_{10}(\text{size}_2/\text{size}_1) + 25 \log_{10}(\text{pressure}_2/\text{pressure}_1) \quad (13)$$

$$10 \log_{10}(\text{capacity}_2/\text{capacity}_1) + 20 \log_{10}(\text{pressure}_2/\text{pressure}_1) \quad (14)$$

These relations also apply only for a fixed point of rating.

A double width fan is essentially two fans of the same size, speed, and sound pressure. Its sound power level will be  $10 \log_{10} 2$ , or 3 db greater than for the single one.

Table 2 . . . Recommended Noise Criteria for Offices<sup>a</sup>

| NC Curve of Fig. 3 | Communication Environment                                                                                                                          | Typical Applications                                                                       |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| NC20 to NC30       | Very quiet office—telephone use satisfactory—suitable for large conferences.                                                                       | Executive offices and conference rooms for 50 people.                                      |
| NC30 to NC35       | Quiet office; satisfactory for conference at a 15-ft table; normal voice 10 to 30 ft; telephone use satisfactory.                                  | Private or semiprivate offices, reception rooms, and small conference rooms for 20 people. |
| NC35 to NC40       | Satisfactory for conferences at a 6-8 ft table; telephone use satisfactory; normal voice 6 to 12 ft.                                               | Medium-sized offices and industrial business offices.                                      |
| NC40 to NC50       | Satisfactory for conferences at a 4-5 ft table; telephone use occasionally slightly difficult; normal voice 3 to 6 ft; raised voice 6 to 12 ft.    | Large engineering and drafting rooms, etc.                                                 |
| NC50 to NC55       | Unsatisfactory for conferences of more than two or three people; telephone use slightly difficult; normal voice 1 to 2 ft; raised voice 3 to 6 ft. | Secretarial areas (typing), accounting areas (business machines), blueprint rooms, etc.    |
| Above NC55         | Very noisy; office environment unsatisfactory; telephone use difficult.                                                                            | Not recommended for any type of office.                                                    |

<sup>a</sup> Noise measurements made for the purpose of rating the noise level in an office by comparison with these criteria should be performed with the office in normal operation, but with no one talking at the particular desk or conference table where speech communication is desired (i.e., where the measurement is being made). Background noise with the office unoccupied should be lower by approximately 5 to 10 units.

Table 1 . . . Recommended Noise Criteria for Rooms<sup>a</sup>  
Noise Levels to be Measured in Unoccupied Rooms

| Type of Space                                                 | Recommended Noise Criterion Curve | Computed Equivalent Sound Level Meter Reading <sup>b</sup> |
|---------------------------------------------------------------|-----------------------------------|------------------------------------------------------------|
|                                                               |                                   | Weighting Scale-A db                                       |
| Broadcast studios . . . . .                                   | NC 15-20                          | 25-30                                                      |
| Concert halls . . . . .                                       | NC 20                             | 30                                                         |
| Legitimate theaters (500 seats, no amplification) . . . . .   | NC 20-25                          | 30-35                                                      |
| Music rooms . . . . .                                         | NC 25                             | 35                                                         |
| Conference rooms for 50 . . . . .                             | NC 25                             | 35                                                         |
| Apartments and hotels . . . . .                               | NC 25-30                          | 35-40                                                      |
| Assembly halls (amplification) . . . . .                      | NC 25-30                          | 35-40                                                      |
| Homes (sleeping areas) . . . . .                              | NC 25-35                          | 35-45 <sup>c</sup>                                         |
| Conference rooms for 20 . . . . .                             | NC 30                             | 40                                                         |
| Motion picture theaters . . . . .                             | NC 30                             | 40                                                         |
| Hospitals . . . . .                                           | NC 30                             | 40                                                         |
| Churches . . . . .                                            | NC 30                             | 40                                                         |
| Courts . . . . .                                              | NC 30                             | 40                                                         |
| Libraries . . . . .                                           | NC 30                             | 40                                                         |
| Small private offices . . . . .                               | NC 30-35                          | 40-45                                                      |
| Schoolrooms (no amplification) . . . . .                      | NC 25-35                          | 35-45                                                      |
| Restaurants . . . . .                                         | NCA 45                            | 55                                                         |
| Coliseums for sports only (amplification) . . . . .           | NCA 50                            | 60                                                         |
| Stenographic offices (typing and business machines) . . . . . | NC 50                             | 60                                                         |
| Factories . . . . .                                           | NCA 40-65                         | 50-75                                                      |

<sup>a</sup> Each noise criteria curve is a code for specifying permissible sound pressure levels in eight octave bands. It is intended that in no one frequency band should the specified level be exceeded. The computed equivalent db numbers in the right-hand column are presented for information only and are no longer recommended for use in specifications. Ventilating systems should be operating and outside noise sources, traffic conditions, etc., should be normal when measurements are made.

<sup>b</sup> If the noise is predominantly in the speech bands so that the spectrum does not have the shape of the recommended noise criterion curve, the recommended values should be lower by 5 db.

<sup>c</sup> Room air conditioners made prior to 1957 commonly produce levels of 50 to 60 db in sleeping areas.