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ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: AIRPORT LANDSCAPING FOR NOISE CONTROL PURPOSES

1. PURPOSE. This advisory circular provides guidance to airport planners and operators in the use of tree and vegetation screens around airports and aircraft operating areas for noise control purposes.

2. BACKGROUND. A number of research studies have been conducted (see Appendix 2) to investigate the sound attenuation properties of trees, shrubs, and other types of vegetation. Through these efforts, it has been demonstrated that tree and vegetative screens can achieve moderate noise attenuation in selective situations. The material contained in this circular summarizes some of the research findings on this subject and discusses the application of tree and vegetative screens on and adjacent to airports for noise control purposes.

3. NOISE ATTENUATION CHARACTERISTICS OF TREE AND VEGETATION SCREENS. The noise attenuation qualities of tree and vegetation screens result from their ability to absorb and diffuse sound waves. Acoustical energy is partially absorbed by plant foliage, such as leaves, needles, twigs, and small branches whereas trunks, heavier branches, and dense foliage scatter or diffuse sound. Thus, tree and vegetation belts act as "leaky barriers" both absorbing and reflecting part of the acoustical energy away from a receiver. The overall noise attenuation capability of tree belts has been shown to be influenced more by belt thickness, height, and overall density of the barrier than by differences in leaf size and shape and branching characteristics. In other words, the process of diffusion is more prevalent than the process of absorption. Absorption characteristics become more influential, however, as the frequency of the noise source increases. Experiments have determined that foliage is more efficient in attenuating sound waves in the higher frequency ranges than in the middle and low ranges and that its effectiveness increases with foliage density, leaf width, and leaf thickness. For example, sound at 4,000 Hz. is reduced

approximately 5 decibels when shielded by a 100-foot width (30 m) of dense foliage whereas sound at 1,000 Hz. is reduced only 2 decibels under similar conditions. This phenomenon is illustrated in Figure 1, developed by Bolt, Beranek, and Newman, Inc., which compares the noise attenuation of different type trees as the frequency of the noise source increases.

4. BELT THICKNESS. The average attenuation for tree belts of various wood species has been found to average approximately 7 dB for a 100-foot (30 m) thick belt within a noise frequency range of 200-2,000 Hz. This occurs, however, only beyond the first 50 feet (15 m) of belt thickness. Belts less than 50 feet are often ineffective and may, under certain circumstances, produce a negative attenuation. The attenuation value has also been found to be nonlinear with respect to belt thickness. This is demonstrated in Figure 2. This chart, developed by Bolt, Beranek, and Newman, Inc., indicates the approximate noise reduction for a four-engine turbofan civil transport aircraft at the start of takeoff roll for increasing tree belt widths. Noise attenuation is expressed in perceived noise decibels (PNdB). The chart demonstrates that the efficiency of tree belts decreases with increasing thickness to the point where there is no additional measurable attenuation beyond a thickness of 800 feet (240 m). This limit is about 15 PNdB.

5. POSITIONING OF SCREEN. The relative positions of the noise source, the vegetation screen, and the receiver are critically important in determining the effectiveness of a tree belt in reducing undesirable noise. The sound absorption and diffusion characteristics of a vegetation screen or tree belt are such that its noise attenuation effectiveness is highly dependent on the source or the receiver being close to the screen. Belt location tests conducted by Cook and Van Haverbeke shown in Figure 3 illustrate this phenomenon. The curve on the graph shows a pronounced "dip" at an R/S ratio (the ratio of receiver-belt distance to source-belt distance) equal to unity. This corresponds to a tree belt placement midway between noise source and receiver and indicates low attenuation and ineffective placement of the belt. The attenuation increases as the R/S ratio increases, indicating that the closer the tree belt to the noise source, the more effective the placement of the belt. The upward turn of the curve at low R/S values, corresponding to a placement of a belt close to a protected area, indicates that some benefit may be realized by having the belt "close in" but not as much as when the belt is placed near the noise source.

6. SHIELDING EFFECT. For a tree belt to be effective, its height must be adequate to provide the necessary shielding between the noise source and the receiver. This shielding effect is illustrated in Figure 4. Note that for a vegetation screen to be effective, the noise source must be relatively close to the ground; for example, sound produced by taxiing

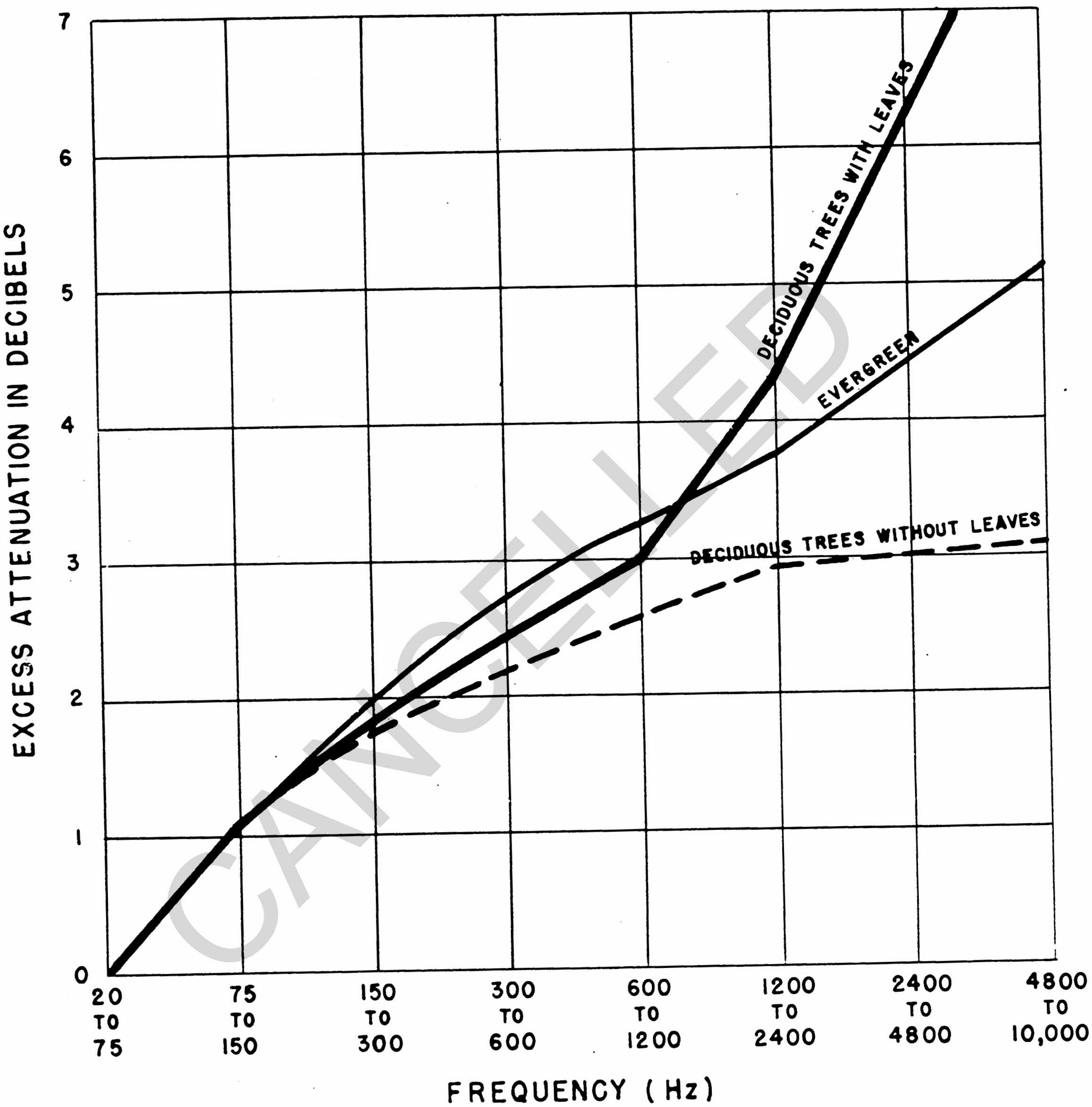


FIGURE I. ATTENUATION OF 100 FT. (30m) THICK TREE BELTS VARYING SOUND FREQUENCIES

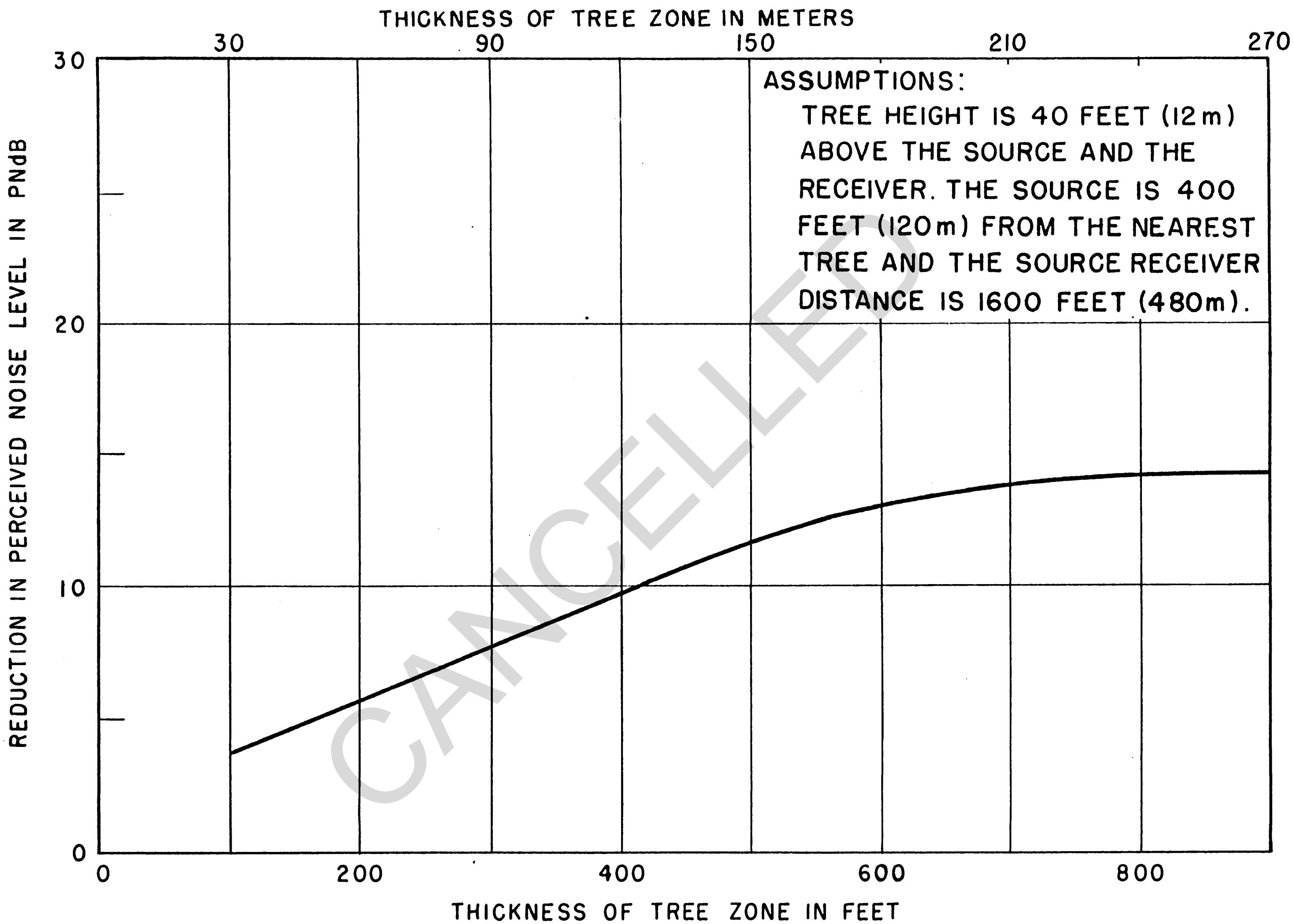
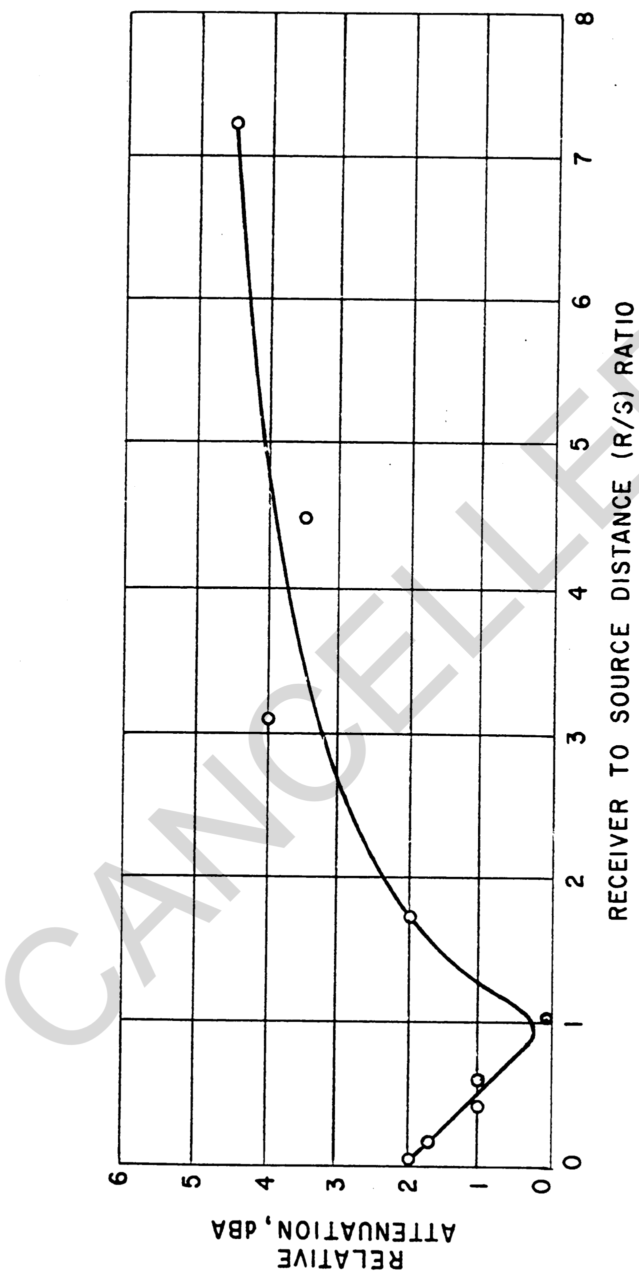


FIGURE 2. APPROXIMATE REDUCTION OF THE PERCEIVED NOISE LEVEL FOR AIRCRAFT NOISE VS. TREE BARRIER THICKNESS



NOTE: R = DISTANCE FROM RECEIVER TO SCREEN
S = DISTANCE FROM NOISE SOURCE TO SCREEN

FIGURE 3. EFFECT OF RELATIVE POSITION OF SCREEN ON NOISE REDUCTION

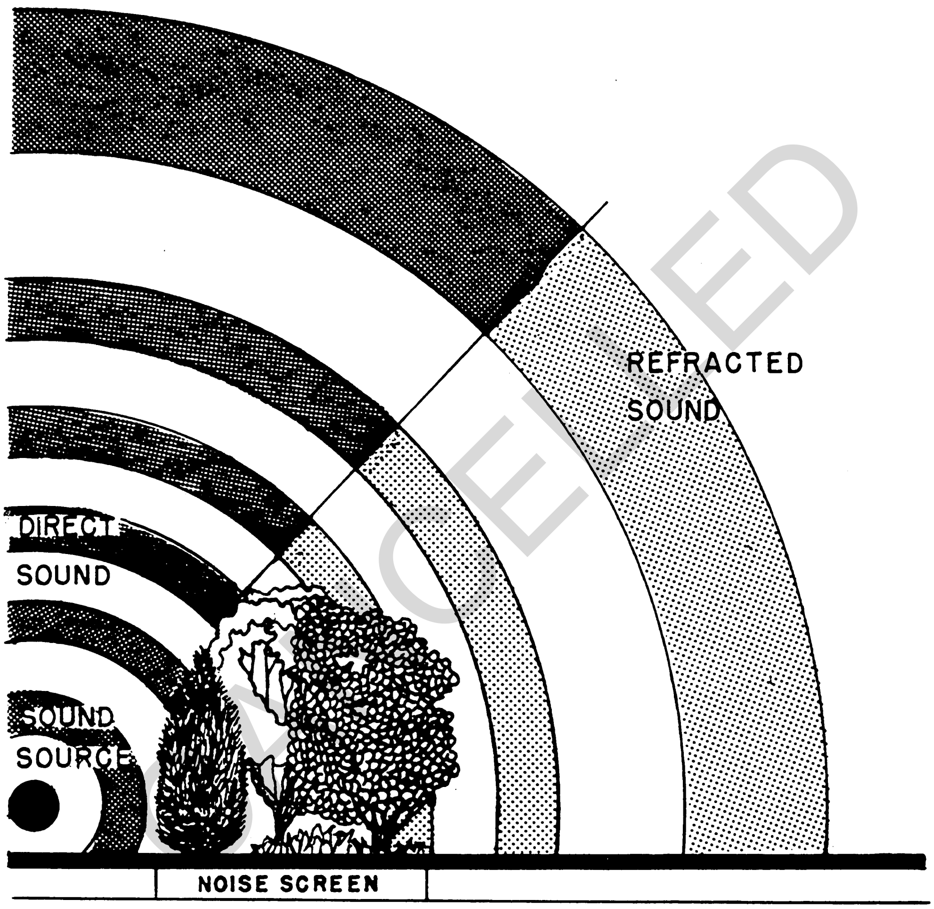


FIGURE 4. NOISE SCREENING GEOMETRY

and parked aircraft. The screen's effectiveness quickly diminishes as the noise generator moves above the top of the trees permitting line-of-sight between the noise source and the receiver (as in the case of airborne aircraft).

7. SURFACE TREATMENT. The softness and texture of a surface that sound passes over can have a marked effect on noise attenuation. This is primarily due to the absorption quality of soft, coarse surfaces as opposed to reflection from a hard, smooth surface. Thus, grass, low shrubs and plantings, vegetation cover, and cultivated earth can, by themselves or in conjunction with trees or other natural or man-made barriers, contribute to noise reduction. Figure 5 shows the results of a test made by Cook and Van Haverbeke which illustrates the variation in noise attenuation over different type surfaces. The chart clearly demonstrates that pavement areas are good reflectors of noise and that the presence of trees, shrubs, plowed earth, and grass alongside such areas can contribute positively to noise attenuation.

8. ATMOSPHERIC GRADIENTS. Atmospheric gradients of wind velocity, temperature, and humidity have recognized effects on sound transmission (and noise reduction). These are discussed below.

a. Wind Velocity. Sound waves are refracted or "bent" upward or downward as a result of changes in the normal velocity of propagation at varying elevations. Downwind propagation, associated with a positive velocity gradient (velocity increasing with altitude) tends to bend the waves downward, thus maintaining audibility at considerable distances. On the other hand, upwind propagation, associated with a negative velocity gradient, tends to bend the sound waves upward and rapidly decreases audibility. Thus, the need for downwind placement of noise screens is greater than for upwind placement since the sound level tends to decrease more rapidly upwind. Tree barriers also tend to modify the wind patterns in a way which favors downwind placement.

b. Temperature. A comparable situation exists with temperature gradients during the day as the sun warms the fields. Positive temperature gradients (temperature increasing with altitude) are typical during early morning and evening hours when the ground is cool, whereas negative temperature gradients are typical during middays when the ground is warmed by the sun. In the summertime, a band of cooler, high density air within a belt of trees may offer some resistance to sound penetration.

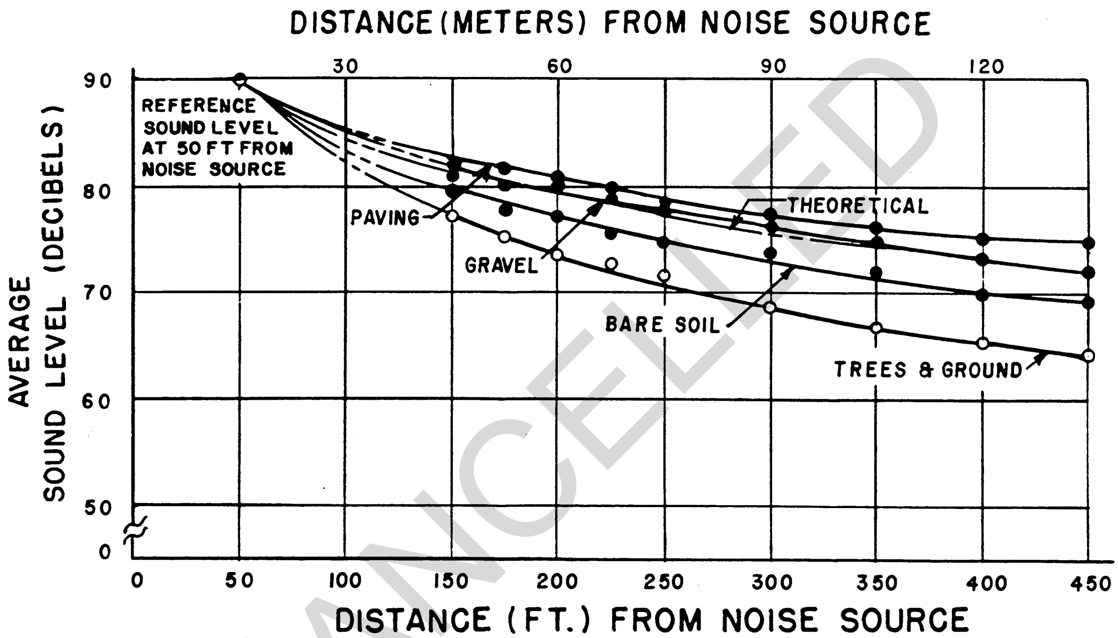


FIGURE 5. SOUND PROPAGATION OVER VARIOUS SURFACES

c. Humidity. Slight variations of humidity appear to have little or no direct effect on the propagation of sound. Extremely high humidity, as during rain or fog, however, tends to produce a more homogeneous atmosphere, and in so doing, favors the propagation of sound. Humidity thus appears to have a relatively minor effect on the use of trees and shrubs for noise abatement purposes.

9. PSYCHOLOGICAL EFFECTS. Over and above the actual noise attenuation properties of tree and vegetative foliage, it has been demonstrated that vegetative screens produce positive psychological effects. Hence, a narrow belt of trees or hedges can be effective in reducing complaints by providing an aesthetic improvement and by shielding the undesirable noise source even though the resulting noise attenuation is negligible. Wind blowing through trees also produces its own noise which is often sensed as a pleasant sound and can help to mask the more offensive and unwanted noises.

10. RECOMMENDED SPECIES. The wide variance in plant life and foliage growth in different climatic zones, together with other factors (e.g., bird population and habits, soil characteristics, etc.), makes it desirable to consult with landscape architects and experts familiar with the local area when selecting specific plants. However, as general guidance, species with large, coarse leaves have been found more effective in scattering low sound frequencies; whereas species with small, dense, finely textured foliage are preferred for diffusing the high frequencies. Deciduous trees in full leaf are more effective than evergreen trees in absorbing and diffusing upper-middle to high frequencies. Figure 1 shows a comparison of the attenuation characteristics of evergreen and deciduous trees at varying frequency ranges. As the chart illustrates, deciduous trees lose their effectiveness when the leaves fall. Thus on a year-round basis, coniferous and broad-leafed evergreens are more effective for noise screening purposes. Evergreen trees and shrubs found suitable for year-round noise screening are listed in Appendix 1.

11. PLANTING PATTERNS. Although tree belts and hedges may provide an aesthetic and psychological benefit in screening airport activities, their acoustical value is quite limited unless the planting is dense and has a minimum thickness of 50-100 feet (15-30 m). To be effective in both winter and summer, the planting of a reasonable mixture of both deciduous and evergreen trees is recommended. The colder the climate or the narrower the belt thickness, the greater the proportion of evergreens required. Border plantings should be lower toward the noise source to direct the unwanted noise upward and away from the receiver. Staggering of trees and shrubs is recommended to avoid channels through which the noise can freely propagate. Dense shrubbery added beneath the tree canopy will provide attenuation of the sound that otherwise would pass below the tree foliage. Such shrubbery is not required throughout the entire tree zone, but can be planted in one or two

20-foot (6 m) bands for every 100 feet (30 m) depth of the tree belt. From an attenuation standpoint, the belt should be located as close as possible to the noise generator or to the area to be shielded and project as high as practical above the noise source without penetrating the imaginary surfaces defined in the Federal Aviation Regulations (FAR), Part 77, Objects Affecting Navigable Airspace, Subpart C. Other considerations and potential hazards as discussed in paragraphs 13 and 14 should be weighed carefully before establishing and locating vegetative screens.

12. VEGETATION IN COMBINATION WITH OTHER ELEMENTS. Tree belts and vegetative screens can be made even more effective if used in conjunction with earth berms or architectural barriers such as walls and concrete or stone embankments. When so used, the earth or architectural barrier should be located closest to the noise source with the trees or other plantings located behind and projecting to a height necessary to achieve the desired shielding. The slopes of earth berms and embankments facing the noise source should be covered with grassy turf, dense shrubs, vines, or other plantings to provide additional sound absorption. If walls are utilized, the dense concrete or masonry type is preferred over fencing or low density type structures. Ivy and other vine plantings on the wall can help further increase the effectiveness of the barrier.

13. LIMITATIONS ON NOISE SCREEN USE. The use of tree belts and vegetative screens on airports for noise control purposes has serious shortcomings and disadvantages that limit their application and require careful planning before their utilization. Some of these are discussed below:

a. Hazards to Aircraft Operations. Areas adjacent to runways and in runway approaches should be kept as free as practical from obstructions and vertically projecting objects. Trees and heavy shrubs in these areas can present a potential hazard in the event of an emergency situation and can contribute to turbulent wind conditions and visual distractions to pilots in making landing approaches. They also provide feeding and nesting areas for birds and other forms of wildlife that can create a serious problem to aircraft operations. This is discussed further in paragraph 14.

b. Obstructions to Air Navigation. To be effective from a noise standpoint, trees and vegetation must be of sufficient height to provide adequate screening. However, to prevent the trees from becoming obstructions to air navigation, their heights must be limited to insure that tree growth does not result in penetration of the imaginary surfaces defined in FAR Part 77, Subpart C. Such penetration can result in a hazard requiring expensive clearing and topping operations, obstruction lighting, and possible imposition of limitations to aircraft operational capability.

c. Facility Interference. The planting of trees and vegetation in proximity to air navigation and communication facilities can, under certain circumstances, interfere with their performance. Prior to selecting any tree planting plan, the airport operator should consult with the local FAA Airway Facilities Sector to determine the potential impact of the proposed planting on FAA facilities located on the airport.

d. Visual Screening of Control Towers. Care must be taken to prevent trees and vegetation from obstructing the line-of-sight between aircraft operating areas and air traffic controllers. Runway ends, taxiway and runway intersections, apron areas, loading gates, and other high traffic locations are particularly sensitive and should be kept free of any visual impediments.

e. Emergency Vehicles. The presence of bands of trees and shrubbery on or in the vicinity of an airport can restrict and impede the operation of Crash/Fire/Rescue (CFR) vehicles in the event of an aircraft crash or emergency. Tree plantings should be planned to insure the accessibility of areas on the airport and in the runway approaches to this equipment.

f. Cost Effectiveness. As suggested in paragraph 6, the noise attenuation effectiveness of tree belts is limited to operations on or close to the surface. Once an aircraft clears the tops of the trees and is within line-of-sight of the observer, minimum, if any, attenuation benefits are derived. Thus, regardless of the extensiveness of a tree belt, only a portion of the aircraft noise generated in the vicinity of an airport is subject to any screening effects. Also, since the planting of mature trees is expensive and generally impractical except for very limited situations, the planting of seedlings and immature young trees is more likely. This increases the maintenance problem and the probability of a higher percentage of plant-kill. It also results in a longer period of time before any measurable noise attenuation can be achieved, since the seedlings and young plants will require a number of years to develop. Hence, unless trees and vegetation already exist, the establishing of tree screens around an airport will likely have a relatively low cost/benefit ratio except at very selective locations.

14. BIRD HAZARD POTENTIAL. Prior to any decision to utilize tree or vegetation screens for noise control, their potential for creating a bird hazard to aircraft must be carefully weighed against the anticipated noise benefits. Wooded areas and vegetation often attract birds by providing feeding, nesting and/or roosting areas. This is particularly true at junctions of wooded areas and grasslands and where two distinctly different vegetative communities join. Hedgerows are also highly attractive as shelters for birds and small mammals and should be avoided. For the same reason, the planting of trees and shrubs is not

recommended closer than 600 feet (180 m) to the centerline of active runways and taxiways. In considering the use of tree and vegetation belts as noise screens, the following factors should be considered: the type, size, feeding, and migratory habits of the area bird population; the geometric relationship and proximity between local feeding and nesting grounds, the proposed noise screen, and aircraft operating areas; and the affinity of the trees and vegetation to attract birds.

15. RECOMMENDED APPLICATION. Despite their obvious limitations, thoughtful, selective use of tree belts and vegetation screens on and in the vicinity of an airport can provide worthwhile benefits without creating serious problems or potential hazards. As already suggested, trees in runway approaches and in proximity to runways, frequented taxiways, and navigation/communication facilities should be avoided. On the other hand, tree belts established along the outer perimeter or fringes of an airport and selective plantings within the terminal area complex, near parking aprons, aircraft maintenance facilities and noise sensitive areas (e.g., schools, offices, public buildings, etc.) can, in conjunction with other noise control techniques, contribute positively to the airport's compatibility with its environment from a noise and aesthetic standpoint.

16. FAA PARTICIPATION IN LANDSCAPING PROJECTS FOR NOISE CONTROL. The Airport and Airway Development Act of 1970 as amended by Public Law 94-353 (The Airport and Airway Development Act Amendments of 1976) categorizes "landscaping for the purpose of diminishing the effect of aircraft noise on any area adjacent to a public airport" under the definition of airport development eligible for Federal grants under the Airport Development Aid Program (ADAP). Consequently, FAA can approve grants for the creation of tree and vegetative screens provided they are planned and located in compliance with the guidelines contained in this advisory circular.

17. HOW TO OBTAIN THIS PUBLICATION. Additional copies of this advisory circular can be obtained free of charge from the Department of Transportation, Publications Section, M-443.1, Washington, D. C. 20590. FAA field personnel may obtain copies from their respective regional Distribution Officers.

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APPENDIX 1. EVERGREEN TREES AND SHRUBS SUITABLE FOR YEAR-ROUND NOISE SCREENING

COMMON NAME	REGIONS OF BEST ADAPTABILITY
TALL	
Fir	
White	Nationwide
Veitch's Silver, Nikko	East
Balsam	Midwest, North, Northeast
Corkbark	Midwest, Southwest, Southeast
Fraser	East, Southeast
California Red	West
Spanish	West Coast
Cedar	
Atlas	West Coast
Deodar, Cedar of Lebanon	West Coast, South, Gulf Coast
Port-Orford Cedar	West Coast, South, Southeast
Arizona Cypress	Southwest, South, Southeast
Spruce	
Norway, White Serbian,	Nationwide (best in North)
Oriental, Blue	Nationwide (best in North)
Pine	
Western White	West
Ponderosa	West, Midwest
Scotch	Nationwide (best in North)
Red	East, North
Austrian, Eastern White	Midwest, East
Monterey	California Coast
Douglas Fir	Nationwide (except South)
Giant Sequoia, Redwood	West Coast
Western Red Cedar	West
Hemlock	
Eastern	East, Southeast
Carolina	East Coast, Southeast, South
Western	West Coast
MEDIUM	
Juniper (upright)	
Eastern Red Cedar and varieties	East of Rocky Mountains
Rocky Mountain and varieties	West of Rocky Mountains, Midwest
Chinese and varieties	Nationwide
Grecian	Nationwide
Irish	Nationwide (best in North)
Swedish	Nationwide (best in North)

COMMON NAME	REGIONS OF BEST ADAPTABILITY
Yew	
Japanese and varieties	Nationwide
English	Nationwide (best in East)
Arborvitae	
American and varieties	Nationwide (best in North, Northeast)
Oriental and varieties	South
	SHORT
Juniper	
Chinese (Pfitzer) and others	Nationwide
Mugo pine	Nationwide
Arborvitae	
American and varieties	Nationwide
Oriental and varieties	Nationwide
Yew	
Japanese and varieties	Nationwide
Some Broad-leaved Evergreens	
Pyracantha	Nationwide (best in South)
Euonymus	Nationwide
Privet	South

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