Community Noise Levels of the DC-10 Aircraft

A. L. McPike*
Douglas Aircraft Company, Long Beach, Calif.

The results of recent flyover noise tests show that the McDonnell Douglas DC-10 aircraft powered by General Electric CF6-6D engines is much quieter than the current jet transport aircraft powered by turbojet or low-bypass-ratio turbofan engines. Several major design features incorporated into the engine and the installation of the engine on the aircraft have accomplished this reduction in noise. The DC-10 will meet the noise level requirements established by the Federal Aviation Administration for new transport aircraft and will, in fact, generate noise levels which are well below the requirements for takeoff and sideline noise. It will also meet the noise level requirements established by the Port of New York Authority and other airport operators at specific noise monitoring stations for normal aircraft operations. The DC-10 represents a major step in the direction of reducing noise pollution in communities around airports.

Introduction

THE McDonnell Douglas DC-10 aircraft should be in regularly scheduled airline service by the first of September, 1971. The DC-10 powered by General Electric CF6-6D engines is the first commercial jet transport to have had community noise requirements as a major design constraint from the initial conception of the aircraft. Noise played a major role in the development of the engine and also in the manner in which the engine was installed on the aircraft.

The domestic version of the DC-10 will carry from 230 to 345 passengers at ranges up to approximately 3500 naut miles. With this capability it will often be performing missions currently handled by four-engine jet transports. But the aircraft has been designed to operate at smaller airports which handle only local traffic as well as at larger airports. A major design goal was to make the DC-10 more compatible with communities around airports than the two- and three-engine jet aircraft currently servicing these airports. This improved compatibility has been accomplished, and the purpose of this paper is to present noise level data for the DC-10 and discuss the community noise levels of the aircraft.

The paper will outline the acoustical design features of the engine and its installation and will provide data which show how well the DC-10 complies with several of its design noise requirements. Data are also presented which compare the community noise levels of the DC-10 with those of current four-engine fan jets such as the DC-8 and 707. Finally, data are presented which show how the noise of the DC-10 compares with that of current two- and three-engine fan jets including the DC-9, 727, and 737.

Design Features for Low Noise

The design features responsible for the low noise of the DC-10 have been described in some detail in Refs. 1 and 2. Because the purpose of this paper is to discuss the results of these features rather than the features themselves, the reader is referred to these two reports for details. A very brief summary of these features is provided below to help the reader understand why the DC-10 has been able to achieve very low airport community noise levels.

There are two basic types of noise on the turbofan engine. One is the low-frequency roar of the jet exhaust that dominates the engine noise at high engine powers such as takeoff thrust. The other is the high-frequency turbomachinery noise which is more noticeable at low engine powers such as those associated with landing thrusts.

The jet exhaust roar results from the turbulent mixing of the high-velocity engine exhaust gases with the ambient air behind the engine. On the high-bypass-ratio engine a high percentage of the air entering the engine bypasses the combustion chamber and leaves the engine through the fan-discharge ducts. The bypass ratio of the CF6-6D is 6.3:1 so that 6.3 times as much air passes through the fan-discharge ducts as through the primary nozzle. The combination of high-bypass-ratio, nozzle area, and other parameters on the CF6-6D have resulted in reduced jet exhaust velocities and greatly reduced jet exhaust noise for the CF6-6D engine on the DC-10. A cutaway view of the CF6-6D as installed on the DC-10 is shown in Fig. 1.

The turbomachinery noise is generated inside the engine by high-speed rotating blades and the stators associated with the engine fan, compressor, and turbine systems. There are two basic approaches to the reduction of this type of noise on the DC-10. The first is in the basic design of the three blade/stator systems. This approach has frequently been referred to as the "new technology fan design" because it was developed primarily for the engine fan system which is usually the most dominant source of turbomachinery noise. This new technology includes such features as eliminating inlet guide vanes, minimizing the fan-blade tip speeds, increasing the spacing between the fan and outlet guide vanes and optimizing the ratio of the number of fan blades and outlet guide vanes to minimize the generation of discrete tones.

The second approach to the reduction of turbomachinery noise is to keep as much as possible of that noise generated within the engine from reaching the airport neighbors. On

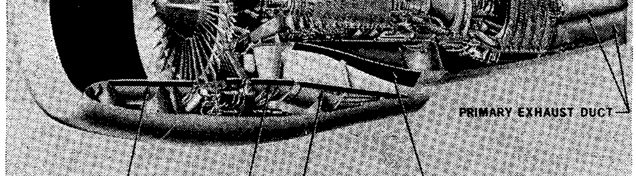

Fig. 1 Major design features for low noise—CF6-6D engine as installed on the DC-10.

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* Director, Industry Association Activities.

the DC-10 this is accomplished by the use of long fan-discharge ducts and sound absorbent lining material in the inlet, the fan case and the fan-discharge ducts. Similar long fan-discharge ducts with no absorbent lining material were demonstrated to reduce the flyover noise of the Series 60 DC-8's by from 2 to 4 PNdb. In addition to the benefits of the longer duct itself, there is more surface area on which to apply absorptive treatment. The absorptive treatments have been demonstrated to be effective on several aircraft, and special absorptive linings were developed for the CF6-6D engine to achieve an optimum reduction of turbomachinery noise. An additional design feature for minimum noise is the use of a single opening inlet at all operating conditions. The use of devices such as blow-in doors to bring additional air into the engine at some engine powers has some aerodynamic advantages but increases engine noise. No blow-in door systems are in use on the DC-10.

Although not developed purely for low noise, the aerodynamic performance of the aircraft is an important contribution to the achievement of low noise levels in many airport communities. The elements of this aerodynamic performance, important to low neighborhood noise levels, include optimized takeoff and climb capability to achieve maximum altitudes over neighboring communities and minimized drag to reduce the engine power required for the aircraft during approach and landing operations and during takeoff operations involving noise abatement thrust reductions. This combination of features has resulted in noise levels which have made it possible the DC-10 to meet all its noise design requirements. In addition, the DC-10 will be much quieter than current jet transport aircraft as discussed below.

FAA Noise Certification Requirements

The DC-10 Program was well advanced when the Federal Aviation Administration adopted the new Part 36 of the Federal Aviation Regulations (Ref. 3). However, these regulations had been under consideration for some time prior to their adoption, and one of the major design requirements for the DC-10 was to meet them.

The FAA established noise requirements for three reference locations as shown in Fig. 2. Reading from the right in the figure, the first location is below the takeoff climbout path at a distance of 3.5 naut miles from brake release. The second location is at some point on a line parallel to and 0.25 naut mile to the side of the runway centerline where the noise level after liftoff is greatest during a takeoff. The third location is directly below the approach path 1 naut mile from the runway threshold.

The noise level requirement for the takeoff location, shown in Fig. 3, is in terms of the effective perceived noise level (EPNL) in units of EPNdb. The required level range is from 93 to 108 EPNdb depending upon the certified takeoff gross weight of the airplane. The DC-10 at its maximum takeoff gross weight of 430,000 lb is required to meet a level of 105.6 EPNdb at the 3.5-naut mile point under the conditions established by the FAA. These conditions include an air

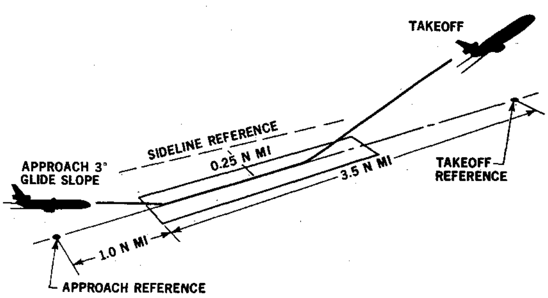


Fig. 2 Aircraft noise certification—reference locations.

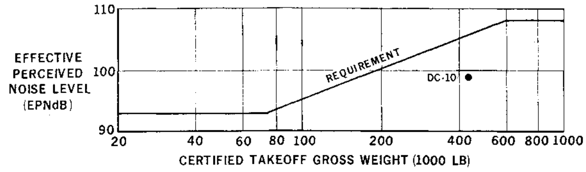


Fig. 3 Noise certification requirement—takeoff; 3.5 naut miles from brake release, 77°F, sea level, no wind.

temperature of 77°F, a relative humidity of 70%, no wind, and a sea level runway.

The level shown for the DC-10 is 99 EPNdb. This number is unofficial because the final noise certification report has not yet been submitted to the FAA.† The 99-EPNdb level was obtained during flight demonstration tests using no noise abatement thrust reduction. Although the aircraft would be permitted to reduce thrust to that level required for level flight in the event of an engine failure before passing over the 3.5-mile location, it was demonstrated with full takeoff thrust. Even without the thrust reduction, the noise level of the DC-10 is well below the FAA requirement.

The noise level requirement for the sideline location is shown in Fig. 4. For this location, the requirement ranges from 102 to 108 EPNdb. At the 430,000-lb takeoff gross weight of the DC-10, the required level is 107.0 EPNdb. The unofficial level demonstrated by the DC-10 is 96 EPNdb, 11 EPNdb below the established requirement. It is important to note that the sideline distance is not the same for all aircraft. For aircraft with three or less engines the distance is 0.25 naut mile. For aircraft with four or more engines the distance is 0.35 naut mile. For a given noise source the difference in noise level between 0.25 and 0.35 naut mile is approximately 4 EPNdb. Thus the noise level of the DC-10, at a distance of 0.35 naut mile where four-engine aircraft are evaluated, would be only about 92 EPNdb.

Figure 5 shows the FAA noise level requirement for the approach condition. The requirement for the DC-10 is again 107 EPNdb, and in this case the level is approximately 2 EPNdb below the requirement.† This requirement offered the greatest design challenge. A major reason for the difficulty is the fact that at 1 naut mile from threshold on a 3° glideslope the aircraft passes over the location at an altitude of only 370 ft. Actually the approach noise level is approximately 4 EPNdb

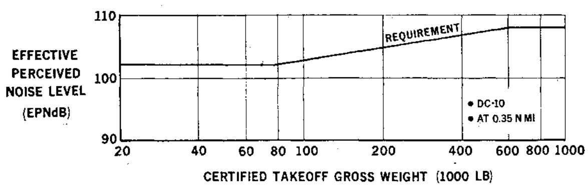


Fig. 4 Noise certification requirement—sideline; 0.25 naut mile from runway.

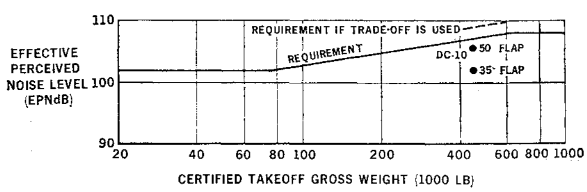


Fig. 5 Noise certification requirement—approach; 1 naut mile from threshold, approximately 370 ft altitude, 3 glide slope.

† See addendum at the end of this paper.

below the requirement.‡ Part 36 permits the DC-10 an exceedance of as much as 2 EPNdb at any one location if that exceedance is offset by being below the requirement at either of the other two locations. Because the DC-10 is well below the requirement for both the takeoff and sideline locations, it would be permitted a level of 109 EPNdb with tradeoff. The aircraft is then actually 4 EPNdb below the maximum permitted level on approach. Alternately, one may think of the DC-10 as meeting the requirement without the need of the tradeoff allowance.

Monitor Noise Levels at Airports

In the past few years, an increasing number of airport authorities have had noise level monitor systems installed in communities near their airports. Many of the specific monitor noise level requirements served as guidance material in the development of the DC-10. The monitor noise requirements which perhaps played the largest role in the design development of the DC-10 were those at La Guardia Airport in New York. That airport, with its heavily populated residential communities located very nearby, installed their noise monitors very close to the runways. One noise monitor (the one beyond runway 22) is located only 1.9 statute miles or approximately 10,000 ft from brake release for takeoff operations. Fortunately, it is only necessary to use runway 22 for takeoff operations a very small percentage of the time. But a design goal for the DC-10 was to meet a level of 112 PNdb at that monitor location after takeoff with the maximum takeoff gross weight for La Guardia operations.

The general layout of La Guardia Airport showing the runways and the noise monitors is shown in Fig. 6. Runway 13 is the one used most frequently for takeoffs, but fortunately its noise monitor station is at a greater distance of 2.9 statute miles (15,300 ft) from brake release. There are no noise monitors beyond runways 4 and 31 because the nearest heavily populated residential communities are much farther away and hence experience much lower noise levels.

Figure 7 shows noise level as a function of takeoff gross weight for the monitor for runway 13. These data are for the least favorable takeoff procedure including no noise abatement thrust reduction and no turns. Aircraft generally turn to the right after takeoff to avoid passing over the noise sensitive community. This maneuver also causes the aircraft to pass farther from the noise monitor and this will result in even lower noise levels for the DC-10. The data are also for unfavorable weather conditions of a 77°F temperature, a 70% relative humidity, and no wind. While the maximum structural design weight of the DC-10 is 430,000 lb, data are not shown above approximately 365,000 lb, which is the maximum allowable takeoff gross weight for DC-10 operations at La Guardia Airport. This maximum gross weight results

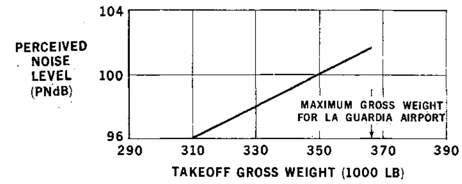


Fig. 7 La Guardia Airport monitor-perceived noise levels—model DC-10; runway 13, no turns, no cutback, 77°F day, no wind.

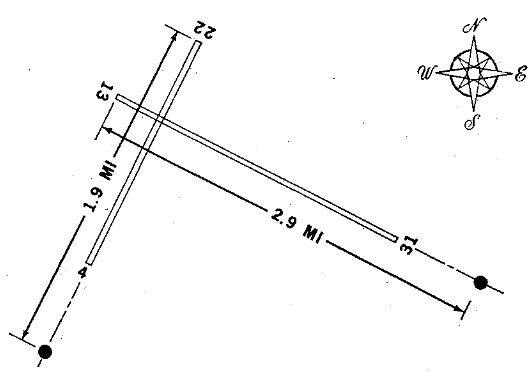
from a load limitation established by the pier which supports part of the runways at La Guardia.

Figure 8 provides similar information for takeoffs from runway 22. The conditions are all as described above except that a headwind of 15 knots has been used. As pointed out above, runway 22 is rarely used for takeoff. It is used only when the winds from the southwest are too strong to permit an acceptable margin of safety for operation on the other runways. The limit is something above 15 knots so that the values for the DC-10 should always be below the values shown. Even with all these pessimistic assumptions, the DC-10 at its maximum takeoff gross weight for La Guardia Airport is well below the 112 PNdb requirement at the noise monitor location as established by the Port of New York Authority.

Comparisons with Current Aircraft

Developing a fair comparison between the noise levels of two different aircraft is a formidable task. There has been no universal agreement on the ground rules for making such comparisons and many different approaches may be used. In some cases one aircraft may be quieter at one location while the other aircraft is quieter at a second location. The noise at any location is a function of the noise generated by the aircraft propulsion system as it goes by and also of the distance between the aircraft and the location. Many airport neighbors experience the noise of aircraft at a variety of distances from the aircraft depending on the flight climb profiles and flight patterns of the aircraft.

One of the major difficulties in a fair comparison is in selecting the appropriate aircraft for comparison. The first aircraft selected for comparision with the DC-10 is the DC-8-61. This was done because these aircraft have approximately the same range capability and thus perform approximately the same mission. The noise levels of the DC-8-61 are typical of those of other current transports powered by four low-bypass-ratio turbofan engines, and the data are approximately applicable to that whole family of aircraft. The comparison is make at the three locations used for FAA certification. Figure 9 shows the relative noise levels of these two aircraft when both are operating at their maximum design



● SOUND MONITOR LOCATIONS

Fig. 6 La Guardia Airport.

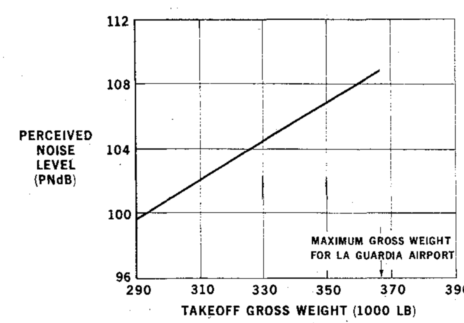


Fig. 8 La Guardia Airport monitor-perceived noise levels—mode DC-10; runway 22, no turns, no cutback, 77°F day, 15 knot headwind.

‡ See addendum for final values.

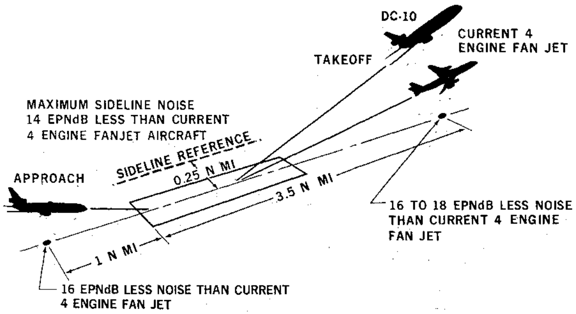


Fig. 9 Flyover noise levels—maximum design weight-model DC-10, maximum design weight.

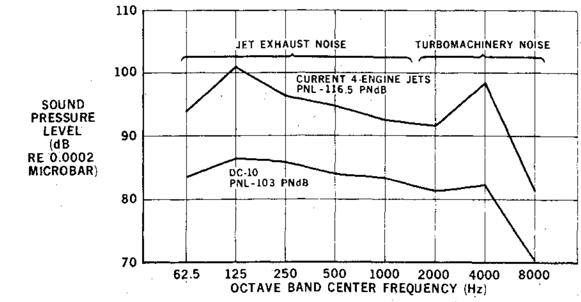


Fig. 11 Flyover noise levels—DC-10 compared to current jet transports powered by four JT3D-3B engines; 75% thrust, altitude 1000 ft.

weights. Below the approach path the DC-10 is quieter than the current aircraft by 16 EPNdb. On the sideline the DC-10 is 14 EPNdb quieter than the current aircraft, and below the takeoff path the DC-10 is 16 to 18 EPNdb quieter than the current aircraft depending on whether or not a thrust reduction is made. The sideline comparison is made at 0.25 naut mile for both aircraft even though the FAR Part 36 sideline distance for four-engine aircraft is 0.35 naut mile. Both aircraft are also the same distance from the noise location for the approach data. For the takeoff location the DC-10 has a greater climb capability, and the 16–18 EPNdb difference accrues from the fact that the DC-10 is basically quieter and also higher than the older four-engine aircraft. These differences are especially significant in light of the fact that the DC-10 is heavier, carries a greater payload, and has engines which are rated at more than twice the thrust of those on the earlier jets. Using the rule of thumb that a reduction of 10 PNdb or EPNdb constitutes a halving of the noisiness of the noise, these differences show that the DC-10 will be less than half as noisy as the earlier jets.

To better understand these noise level reductions and relate them back to the DC-10 design features for low noise, the frequency content of the noise needs to be examined. Figure 10 shows octave band sound pressure levels measured for the DC-8 and DC-10 at an altitude of 1000 ft with all engines at takeoff thrust for both aircraft. The data show that large reductions in noise were achieved at all frequencies. The high-bypass-ratio of the CF6-6D engine as installed on the DC-10 achieved a reduction of 9–16 db over most of the frequency range of the jet exhaust roar. At the higher frequencies, where turbomachinery noise dominates, reductions of 9–13 db were achieved. The reductions achieved in turbomachinery noise have resulted from the new technology fan design of the CF6-6D engine and from the long duct pod and acoustical treatment installations. Of course, the DC-10 has one engine less than the earlier aircraft, but the reduction in eliminating one of the four engines on the earlier aircraft would only be 1.2 db. A PNL reduction of 11.5 PNdb was achieved from the indicated reductions in the spectrum. Most of the remaining perceived noise comparisons presented are in terms of the PNL rather than EPNL because in several cases reliable data were not available in terms of the more complex EPNL.

FAR Part 36 permits, in most cases, the use of a noise abatement thrust reduction to minimize the noise level at the 3.5-mile point. The thrust may be reduced to that power required to maintain level flight in the event of the failure of one engine. This thrust is approximately 75% of takeoff thrust for most commercial transport aircraft. Figure 11 compares the fequency content of the DC-8 and DC-10 at this thrust level. In this case the jet exhaust noise is down 9–14 decibels. The turbomachinery noise is down 10 to 16 db. In general, the reductions in jet exhaust noise are about the same as at takoff thrust. The reductions in turbomachinery noise are even greater than at takeoff thrust and the resultant reduction in PNL is 13.5 PNdb. Approach thrust data are shown in Fig. 12 for an altitude of 400 ft. These data are for a typical approach thrust for both aircraft rather than the thrust for maximum landing weight specified by the FAA in Part 36. The reduction in turbomachinery noise is still very large, varying from 10 to 18 db. The reduction in jet exhaust noise is still substantial but not as great as at high thrust conditions.

An examination of the data in Figs. 10–12 leads to two general conclusions. First, the turbomachinery noise on the DC-10 is greatly reduced compared to that of the earlier aircraft at all operating conditions. Second, the jet exhaust noise is substantially reduced at low engine thrusts and is greatly reduced at the high engine thrusts compared to that of the earlier aircraft. Three years ago the author proposed methods of rating the community noise exposure of different aircraft (Ref. 4). The essence of the proposal was that to ensure noise reduction benefits for all airport neighbors when evaluating quieter aircraft, the reductions must be obtained not only close to the aircraft and out of doors but also at greater distances from the aircraft and indoors. Table 1

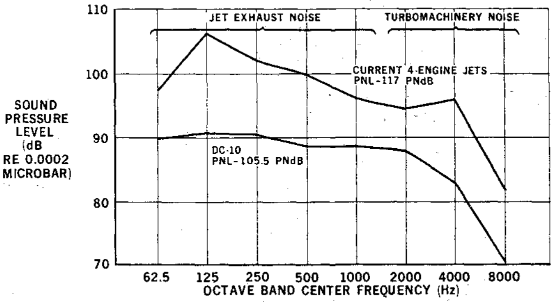


Fig. 10 Flyover noise levels—DC-10 compared to current jet transports powered by four JT3D-3B engines; takeoff thrust, altitude 1000 ft.

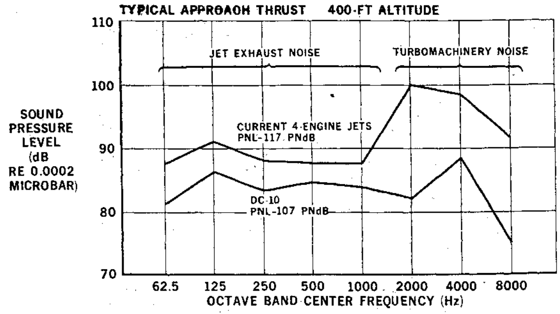


Fig. 12 Flyover noise levels—DC-10 compared to current jet transports powered by four JT3D-3B engines; typical approach thrust, altitude 400 ft.

Table 1 Noise level of the DC-10 relative to those of current 4-engine jet transport[a]

Takeoff	1000 ft outdoors	3500 ft indoors
Full thrust	−11.5	−15
75% thrust	−13.5	−13
	400 ft outdoors	1500 ft indoors
Approach Typical thrust	−10	−11

[a] Current jet transports powered by four JT3D-3B engines, relative levels in units of PNdb.

provides data in terms of reductions in perceived noise level under both types of conditions. The greater distances used were 3500 ft for takeoff thrust and 1500 ft for approach. The data close to the aircraft and outdoors have been presented above. The data for greater distances were obtained from the same measured data with extrapolations as required using SAE Aerospace Recommended Practice No. 866 for air attenuation and SAE Aerospace Information Report No. 1081 for standard values of house attenuation. The house attenuation values used were for a typical or average house with doors and windows partially open.

The data in the table show that the reductions achieved indoors at the greater distances are generally as large or larger than the outdoor reductions achieved closer to the aircraft. This is true even at approach thrust. At this thrust condition the turbomachinery noise of the JT3D engine is so high relative to jet exhaust noise that it dominates the PNL even indoors at 1500 ft.

For many people it is difficult to appreciate just what all these noise level differences mean without hearing the aircraft. To some, their significance may be more easily understood by an examination of noise contours or lines of equal perceived noise level. Figure 13 presents contours of 100 EPNdb during landing and takeoff of the same aircraft compared above. These contours show how far a noise level of 100 EPNdb extends into the airport neighborhood as the aircraft land and take off. Inside the contour the level would go above 100 EPNdb. Outside the contour the level would never be as high as 100 EPNdb. In the figure the observer is looking down from above the airport, and the aircraft is landing from the left on a straight-in approach. The aircraft takes off to the right and climbs out with no turns. These contours are sometimes referred to as the noise footprints of the aircraft. In terms of the area around the airport exposed to a level of 100 EPNdb, it is dramatically smaller for the DC-10 than for the older jet. The level of 100 EPNdb was not selected as indicating any level or degree of acceptability. Similar reductions in contour size would be achieved by the DC-10 compared to the earlier aircraft if some other contour noise level had been selected.

Based on all these analyses there can be little question that the DC-10 is dramatically quieter than the DC-8/707 type aircraft. But the DC-10 will be operating into many airports

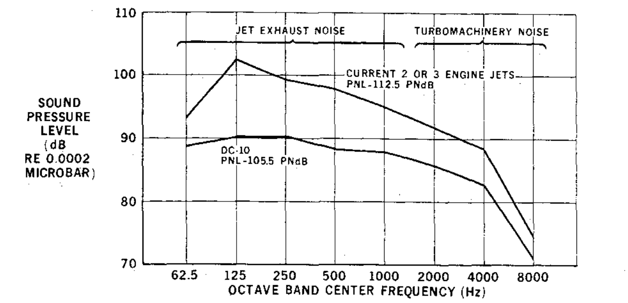


Fig. 14 Flyover noise level—DC-10 compared to current jet transports powered by 2 or 3 JT8D engines; takeoff thrust, altitude 1000 ft.

where the large aircraft do not operate. The question then becomes how do the sound levels of the DC-10 compare with those of the DC-9, 727 and 737 aircraft, all of which are powered by the JT8D engine. Comparisons with these aircraft can become quite complex because of the varied ranges of all four aircraft and because there are differences among the three older aircraft. To simplify the evaluation, the noise level of the DC-10 will be compared with noise levels which are approximately an average between aircraft powered by two and three JT8D engines at the 100%, 75%, and typical approach thrust values used above. The JT8D data presented were actually based on levels measured on a DC-9, but measurements made on the other aircraft show that the data represent approximately the noise characteristics of all three aircraft.

Figure 14 presents the octave band spectra for the DC-10 and for the "average of current two- and three-engine fan jets" at takeoff thrust at an altitude of 1000 ft. The data show the jet exhaust roar of the DC-10 to be 7–12 db below that of the current aircraft over most of the frequency range. The turbomachinery noise is down 6–7 db except in the 8000-Hz band which is reduced about 4 db. The very high frequency noise is difficult to assess properly at high altitudes because of high and variable values of air attenuation. The reduction achieved by the DC-10 in the 8000-Hz band may be larger than shown. The reduction in jet exhaust noise for the DC-10 at takeoff thrust is nearly as great as it was compared to the four-engine aircraft. The reduction in turbomachinery noise is less, but this is because the JT8D engine does not have as much turbomachinery noise at takeoff thrust. It is probable that the high-frequency noise shown for the JT8D engine is, in fact, jet exhaust noise. The reduction in PNL is 7 PNdb.

The data for 75% thrust are shown in Fig. 15. The jet exhaust noise of the DC-10 is 5–7 db below that of the current aircraft. The turbomachinery noise is generally about 4 db below that of the current aircraft. The reduction in PNL is approximately 4.5 PNdb.

Figure 16 presents the data for typical approach thrust.

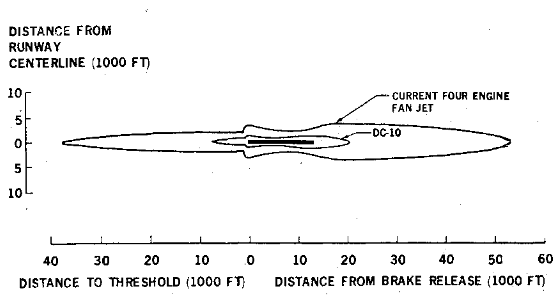


Fig. 13 Contours of 100 EPNdb during landing and takeoff operations—maximum design weights.

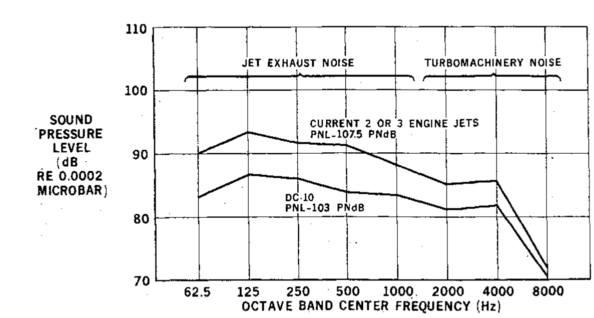


Fig. 15 Flyover noise levels—DC-10 compared to current jet transports powered by 2 or 3 JT8D engines; 75% thrust, altitude 1000 ft.

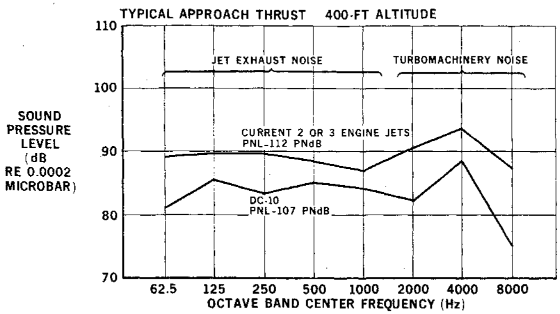


Fig. 16 Flyover noise levels—DC-10 compared to current jet transports powered by 2 or 3 JT8D engines; typical approach thrust, altitude 400 ft.

There is a reduction of 4–8 db in jet exhaust noise over most of the frequency range. The turbomachinery noise is reduced by 5–12 db. At this location the PNL is controlled by the turbomachinery noise and a reduction of 5 PNdb is achieved for the spectrum shown. The data in Figs. 14–16 show substantial reductions in turbomachinery noise at all operating conditions. Reductions in jet exhaust noise are also substantial at all conditions. The reduction in jet exhaust noise at takeoff is, in fact, very substantial and subjectively quite dramatic.

Table 2 summarizes the reductions in PNL achieved by the DC-10 compared to the current two- and three-engine transports powered by the JT8D engine. Data are presented for the same distances and conditions that were used for the comparison to the four-engine aircraft presented in Table 1. The data show that the benefits achieved outdoors near the aircraft are also achieved indoors at greater distances from the aircraft. The dramatic reduction in jet exhaust noise at takeoff is, in fact, reflected in the reduction of 11 PNdb indoors at 3500 ft.

Table 2 Noise level of the DC-10 relative to those of current 2- and 3- engine jet transport[a]

Takeoff	1000 ft outdoors	3500 ft indoors
Full thrust	−7	−11
75% thrust	−4.5	−6
Approach	400 ft outdoors	1500 ft indoors
Typical thrust	−5	−6

[a] Current jet transports powered by fou rJT3D-3B engines, relative levels in units of PNdb.

Summary and Conclusions

The data presented have shown that the DC-10 incorporates a number of new advances in engine noise technology and that with these advances it will meet all its design requirements for low-neighborhood noise levels. These include both the new noise certification requirements established by the FAA in FAR Part 36 and noise monitor requirements such as those at La Guardia Airport in New York. The DC-10 is dramatically quieter than the current jet transports powered by four low-bypass-ratio turbofan engines at all conditions. The areas around airports exposed to a given noise level by the DC-10 will be only a small percentage of the area exposed by the current four-engine transport. The DC-10 is also substantially quieter than the current two- and three-engine jet transports such as the DC-9, 727, and 737. Compared to these aircraft the jet exhaust noise of the DC-10 will be greatly reduced for takeoff operations and the fan noise is substantially reduced at all conditions. The DC-10 represents a major step toward a solution to the airport neighborhood noise problem.

Addendum

The final noise level values approved by the FAA for the DC-10 at the maximum operating weights for the aircraft are as follows: Takeoff 99 EPNdb, sideline 96 EPNdb, and approach 102 EPNdb (with 35° landing flap setting), 106 EPNdb (with 50° landing flap setting). The 102 EPNdb value is the more representative value for the DC-10 on approach. The landing distances for the aircraft are short enough and the approach speeds are low enough that the DC-10 can land with 35° flaps even at maximum landing weight at nearly all airports in the world serviced by medium range jet transport aircraft. The takeoff value is without the use of any power cutback. A takeoff noise level of 96 EPNdb is estimated for the case in which the FAA allowable power cutback is used. In addition, many of the DC-10s are certified to a maximum takeoff gross weight of only 410,000 lb for which the FAA approved takeoff noise value is only 98 EPNdb.

References

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[3] Federal Aviation Regulations, Pt. 36, *Noise Standards*, FAA, Washington, D. C.

[4] McPike, A. L., "Evaluation of Advances in Engine Noise Technology," Douglas Paper 5631, Sept. 1969, *Eleventh Anglo-American Aeronautical Conference*, London, England.