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The Noise Benefits Associated With Use of Continuous Descent Approach and Low Power/Low Drag Approach Procedures at Heathrow Airport

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Directorate of Operational Research and Analysis
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DORA Report No. 7807

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The Noise Benefits Associated With Use of Continuous Descent Approach and Low Power/Low Drag Approach Procedures at Heathrow Airport

A report prepared for the Department of Trade

SUMMARY

The Directorate of Operational Research and Analysis (DORA) measured the approach noise levels and observed the aircraft configurations and flight paths of some 700 westerly approaches during two periods in 1976 and 1977. From these data the average reductions in peak noise level resulting from use of the Low Power/Low Drag (LP/LD) and Continuous Descent Approach (CDA) procedures have been estimated and the areas over which the reductions apply, inferred.

From the reductions in noise level and the observed numbers of approaches implementing the procedures a tentative estimate of the reduction in Noise and Number Index (NNI) in areas under westerly approaches, resulting from use of the procedures, has been made.

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CONTENTS

1 INTRODUCTION

1.1 Two features of traditional approach procedures which give rise to unnecessarily high noise levels are long, level-flight, segments to intercept the glide-path from below and the extension of flaps and undercarriage earlier than necessary in the approach. The first feature is avoided if aircraft can achieve a "Continuous Descent Approach" (CDA) to the glide-path: the second is avoided if aircraft captains implement some form of the IATA*-recommended Low Power/Low Drag approach procedure (LP/LD). These procedures are separate procedures which confer benefits in different areas under the approach. One is not implicit in the other but they can, when conditions are right, be applied in combination.

1.2 The ability of pilots to implement these procedures is dependent - apart from good meteorological conditions - on the ATC environment. ATC must assign higher approach speeds than hitherto and pass to the pilot accurate "distance-to-go-to-touchdown" information during intermediate and final approach.

1.3 In February 1976 the National Air Traffic Services (NATS) introduced measures which were designed to promote wide use of both LP/LD and CDA procedures on westerly approaches. After several months experience in applying these new measures a NOTAM† was issued in December 1976 which defined the new measures and explained their purpose. In July 1977 this NOTAM was amended to provide the same ATC conditions on easterly approaches.

1.4 In April 1976 and again in March 1977 the Directorate of Operational Research and Analysis (DORA) of the CAA undertook field measurements aimed at providing data for a study to assess the effect of the new conditions on the operational efficiency of the ATC system and to evaluate the noise benefits which use of the procedures produced.[1] This note describes briefly the evaluation of these noise benefits and also gives some findings from the operational aspects of the study.

2 THE LP/LD AND CDA PROCEDURES

2.1 The LP/LD procedure

2.1.1 There is no unique version of this procedure which is practised on all aircraft types nor even by different operators on the same aircraft type. The procedure, which originated at Frankfurt, has as its aim the maintenance of the cleanest possible aircraft configuration for as long as possible during each stage of the approach without prejudicing safety. The cleaner configuration reduces aircraft drag and the lower thrust thus required results in a reduction in noise levels beneath the approach path. The procedure requires certain minimum weather conditions: 3 km visibility and 1000 ft cloudbase is typical although there is some variation according to operator.

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* IATA: International Air Transport Association

† NOTAM: NOtice To AirMen

2.1.2 The important feature of the procedure, as practised by Lufthansa and originally recommended by IATA in October 1973, was that in general no more than intermediate flap was extended during the approach until just prior to the Outer Marker - say 5 nm from threshold - when landing gear and full landing flap were extended to stabilize the aircraft configuration by the Outer Marker. Speed was then reduced to stabilize landing speed by 1000 ft above threshold. At the same time the procedure stated that the glide-path intercept provided should not be less than 3000 ft. In weather conditions below the stated minima the procedure was not necessarily precluded but stabilization was effected much earlier during the approach.

2.1.3 More recently, IATA has revised the specification of the recommended procedure. The current specification defines only aircraft speed at various points during the approach, aircraft configuration appropriate to speed being left to the discretion of the operator. This is in contrast to the original recommendation where the extension and timing of landing gear and flaps were specified in a general manner. Another change was the substitution of a minimum glide-path intercept of 2000 ft for the 3000 ft originally recommended. In relation to the original specification the new specification allows wide variations in configuration and glide-path intercept during approach. Thus, whilst individual operators' differing flap and gear schedules might all satisfy this current IATA specification, there could be significant differences, even for the same aircraft type, between the effectiveness of these different schedules in reducing approach noise. It is therefore important that, when the higher-speed environment is provided by ATC, operators should endeavour to use the most effective LP/LD procedure possible for any particular aircraft type.

2.2 The CDA procedure

2.2.1 The CDA procedure is largely self-explanatory and is illustrated at Figure 1. After passing through the reporting point or leaving the stack, the pilot is given descent clearance and informed by ATC of his distance to go to touchdown. This information enables him to select a rate of descent which will allow the aircraft to intercept the glide-path whilst still descending thus avoiding the level segment of flight to intercept the glide-path from below which has for long been regarded as orthodox procedure. Ideally, "distance-to-go" information is updated by ATC during intermediate approach and a final estimate is given in the area of glide-path interception.

2.2.2 Unlike LP/LD, where noise reduction on the ground derives entirely from reduction in source noise, the noise reduction resulting from CDA is comprised of two elements. Over the area where the aircraft would traditionally be flying level to intercept the glide-path, CDA provides a reduction in source noise by virtue of the lower thrust required for descending flight. This is termed CDA thrust benefit. The second element of noise reduction is provided by the attenuation of noise on the ground resulting from the increased height of an aircraft performing CDA over that of an aircraft on the same track flying a level segment prior to glide-path interception. This is termed CDA height benefit and is additive to CDA thrust benefit yielding CDA total benefit. Separate consideration of these two elements is necessary because CDA thrust benefit is sensibly constant over its duration (for a constant angle of descent) whilst CDA height benefit varies according to distance from threshold.

3 ESTIMATION OF THE NOISE BENEFITS OF LP/LD AND CDA PROCEDURES

3.1 General considerations

3.1.1 The use of LP/LD and/or CDA procedures on any flight reduces the aircraft noise heard on the ground in certain areas under the approach paths. When any proportion of arriving aircraft use the procedures the general noise exposure is reduced. The reduction in noise exposure will depend on the amount by which the noise levels of individual approaches is reduced and on the number of approaches achieving these reductions by implementing the procedures.

3.1.2 In order to determine directly the reduction in noise exposure between any two points in time - say from one year to another - very large numbers of measurements of aircraft noise levels would be required at several points on the ground between 5 and 15 nm from the airport at the times in question. Such large samples of aircraft noise levels would normally be collected by automatic monitoring but the data acquired by automatic monitoring would give no information on the extent of the use of each procedure at the times in question neither could the separate benefits of each procedure be readily discerned in any analysis. Without this knowledge it is not possible to judge the general effectiveness of execution of each procedure nor the extent to which the use of the procedures increases with time. Moreover any assessment of the ultimate potential of the procedures to reduce noise exposure is not possible. In order to achieve these objectives it is necessary to use attended-monitoring so that observation of an aircraft's configuration and flight path can be made in addition to measuring its noise level. However, attended-monitoring is expensive in man-power and consequently sample sizes are restricted.

3.1.3 As a supplement to the study described here, the CAA has sought the cooperation of operators by asking them to fly closely-defined approach procedures on specific flights of an individual aircraft type during normal operations into Heathrow. DORA arranges special monitoring of these flights in order to obtain more precise estimates of the potential noise benefits of LP/LD and CDA on these individual aircraft types. (This is in contrast to the results presented here which, as will be seen later, are average values for all aircraft types and for the variation which exists in the application of the procedures.) Aer Lingus Boeing 737 aircraft have already been evaluated in this way and a report will shortly be issued. British Airways Trident 3 aircraft will be the subject of similar trials in the near future.

3.1.4 The following sections describe the method of data collection and analytical methodology adopted to enable estimates of noise benefit to be made with the objectives described in section 3.1.2 in mind. It should be noted that whereas the average reduction in peak noise level on approach resulting from use of the procedures and the proportion of aircraft using the procedures have been obtained by direct measurement or observation, the areas over which these reductions obtain and the effect of the reductions in reducing noise exposure have been obtained by resorting to a reasonable degree of inference.

3.2 The Data Collected for the Analysis

3.2.1 DORA performed two sets of field measurements. In April 1976, in the preliminary set, data relating to some 330 approaches were collected. In March 1977, the main field measurements were commenced but due to adverse weather conditions, noise data on only about 400 approaches were collected.

3.2.2 The data collected for each approach were as follows:-

(i) The peak noise level (dBA) at three monitoring points - approximately 10.6, 8.7 and 6.5 nm from the thresholds and on the extended centrelines of both runways 28L and 28R.

(ii) The position of the landing gear as the aircraft passed each monitoring point. Binoculars were used for this purpose.

(iii) The plan position and height during intermediate and final approach, at 12 second intervals (the period of two radar sweeps) derived from radar output, up to the point where the pilot announced that the aircraft was established (closing heading). In the main field measurements radar output was continued to the point where the aircraft was established on the glide-path.

The purpose of these data was to establish aircraft peak noise level, configuration and flight path as the aircraft passed each noise monitor.

3.3 Methodology

3.3.1 The basis of the analytical methodology is that there is sufficient data on each approach to allow it to be placed in one of four possible classes of approach at each monitoring point. These classes are:-

Class 1	CDA and LP/LD
Class 2	CDA but not LP/LD
Class 3	LP/LD but not CDA
Class 4	Neither LP/LD nor CDA

3.3.2 If the peak noise level associated with each approach at each monitor is placed in the appropriate class then at each monitoring point we have four distributions of peak noise level, whose arithmetic averages will reflect the average noise benefit of each procedure. The differences in arithmetic average peak noise levels in each class provide estimates of benefit and statistical significance testing can be used to reject the hypothesis that such differences could have arisen through sampling variation. Moreover, by employing a degree of inference it is possible to define the areas over which such benefits apply. The proportions of the total sample which fall into each class provide estimates of the incidences of either procedure.

3.3.3 The criterion for labelling an approach as "LP/LD" or "not LP/LD" at any monitor cannot be derived from the current IATA specification of the procedure because this specification is not explicit about aircraft configuration at points during final approach and aircraft configuration represents the only practicable method of identifying an aircraft using an LP/LD procedure. If, however, it is accepted that the original IATA recommendation defines a model LP/LD procedure, then the position of the undercarriage provides an obvious and adequate criterion. An aircraft employing the LP/LD procedure as defined in the original recommendation would have landing gear retracted when passing all three monitoring points. Thus, at any monitor, only aircraft observed to have their landing gear still retracted are classified as performing an LP/LD procedure at that point.

3.3.4 The radar output from which the aircraft flight path is determined gives height information which is too coarse to allow the aircraft rate of descent past any monitoring point to be calculated with precision. On the other hand the radar data enables the duration and height of any segment of sensibly level flight to be readily discerned. Thus the criterion for labelling any part of an approach as CDA is simply that the aircraft is not in level flight at that point.

3.3.5 It will be apparent that any estimates of noise reduction based on these criteria will be average values - average for the varying LP/LD procedures and different degrees of CDA. Moreover, since the sample sizes obtained do not permit an analysis of individual aircraft types the values estimated are average for all aircraft types.

4 RESULTS

4.1 The basic results are shown in Tables A1 and A2 of the Appendix. Table A1 shows the arithmetical means, standard deviations and sample sizes of aircraft peak noise levels within each class of approach at each monitoring point on runways 28L and 28R for the combined data of 1976 and 1977. It will be noted that the data for the Outer Monitoring Point on 28R have been omitted. They were discarded because background noise levels at this monitoring point were subsequently found to be high enough to lead to serious underestimation of noise benefits; in the particular form of analysis used, high background noise levels always lead to underestimation of noise benefits. The data for the Middle Monitoring Point on 28R are also affected in this way but to a much lesser extent and were therefore worth retaining.

4.2 Table A2 shows the estimates of the average noise reduction for each procedure from the data of Table A1. Estimates of average noise reduction are obtained from the difference in arithmetic mean peak noise levels between two appropriate classes for the combined data of 1976 and 1977. This is provided that statistical testing shows it highly improbable that the differences in means arose by chance and further, that the composition by aircraft type of each class was similar and not unrepresentative of the Heathrow mix. The estimates of Table A2 all fulfill these conditions and it should be noted that no sample of less than 30 aircraft has been used to provide an estimate.

5 ANALYSIS AND DISCUSSION

5.1 The LP/LD and CDA noise benefits

5.1.1 In round figures, the average reductions in peak noise level on an aircraft approach which uses either LP/LD or CDA are estimated to be:

3 dB for LP/LD

4 dB for CDA thrust benefit plus
a further CDA height benefit varying
from 0 to 5 dB depending on the distance
from threshold.

Now these reductions are in relation to the basic ILS precision approach procedure - the "traditional" procedure - and before the areas under the approach path over which the reductions apply can be inferred, it is necessary to describe the traditional procedure.

5.1.2 The traditional approach procedure may be typified as "a 6 nm segment of level flight at 3000 ft to intercept the glide-slope, landing gear and either intermediate or full landing flap being extended at about 2 nm before interception". On this basis the LP/LD noise reduction would start at about 11 nm from threshold and extend down to 5 nm before threshold for a rigorously-applied LP/LD procedure, although in many cases the procedure would be terminated before 5 nm. The CDA total benefit would extend over the area 9-15 nm before threshold having a value of 4 dB at 9 nm rising to 9 dB at 15 nm.

5.1.3 Figures 2(a) to 2(e) form a graphical presentation of the noise reductions and the areas over which they apply. It is emphasised that they are the average reductions in peak noise level directly under the flight path on any single aircraft approach on which the procedures are used. The LP/LD benefit will be obtained at all lateral distances from the flight path and only at lateral distances approaching 5000 ft will the CDA benefit be significantly diminished.

5.2 Reduction in noise exposure resulting from use of the procedures

5.2.1 The measure of noise exposure commonly used is the Noise and Number Index (NNI), defined as NNI = $\bar{L}$ + 15 log N - 80 where $\bar{L}$ is the logarithmic mean peak noise level of all aircraft heard and N is the number of aircraft. The trials data do not form a sufficient basis for the calculation of NNI contours for comparison with well-based NNI contours of previous years. Furthermore there are other factors, not related to LP/LD and CDA benefits, which enter such a comparison. However, reductions in NNI attributable to the effect of the procedures alone can be roughly inferred given certain assumptions.

5.2.2 It is clear that if N remains unchanged the value of NNI is reduced by the same numerical amount as $\bar{L}$ is reduced.* The reduction in $\bar{L}$ achieved by use of the procedures depends not only on the average reduction in peak noise level for a single approach but also on the proportions of approaches on which the procedures are implemented. Using Figure 3, the reduction in $\bar{L}$ is readily established given the magnitude of the average noise benefit and the percentage of aircraft producing it. The consequent reduction in NNI, like the noise reduction for a single flight, will apply directly under the flight path and extend laterally from the flight path although the reduction in NNI will be slightly diminished at the larger lateral distances in certain areas. The reductions in NNI apply only if the NNI at any point is not dominated by take-off noise from easterly take-offs.

5.2.3 Taking the datum noise exposure as that where the incidence of either procedure is nil, Figure 4 shows the reductions from this datum which were being achieved at 1972 or prior to it and at 1977 as a result of LP/LD and CDA procedures. It was necessary to establish the position at 1972 by judgment since no suitable observed data are available for any time before the first DORA trials in 1976. In 1972 or earlier we judged that the incidence of LP/LD would not have been greater than 10% - at that time the procedure had not been established at Frankfurt. Further, the incidence of CDA at 1972 or before is conservatively estimated as no more than 20%. These two judgments form the basis of the 1972 line on Figure 4. At March 1977, the observed incidences of the procedures, based on the approaches analysed were:

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*Examination of the number of annual arrivals at Heathrow over the last eight years does in fact indicate that the term 15 log N may be treated as sensibly constant.

CDA .... 54% of all approaches

	(At 817 nm before threshold	68% of all approaches
LP/LD	(	
	(At 6.5 nm before threshold	39% of all approaches

These incidences have been used in constructing the 1977 line in Figure 4. In relation to the figures above, it should be remembered that it is accepted by some operators that the LP/LD procedure can, where weather conditions are not extreme, be sustained down to about 5 nm before threshold.

5.2.4 In July 1977, subsequent to the DORA study, NATS conducted a small study which indicated that the incidence of CDA had risen to about 70% but this was a more approximate assessment than that of the DORA study: no measurements of noise or observations of LP/LD were made in this NATS study. The effect of a 70% incidence of CDA is shown in Figure 4.

5.2.5 The difference in NNI between 1972 and 1977 is an approximate estimate of the reduction in noise exposure which has resulted from an increased incidence in both LP/LD and CDA procedures in that period. It can be assumed that the major part of the increased incidence followed the promulgation of the new ATC regime in February 1976, for prior to then the ATC environment was not conducive to any substantial exploitation of the procedures. Examination of Figure 4 shows that it is difficult to make a precise statement of NNI reduction for the whole of the area under approach, but it can be stated that the greater part of the area between 5 and 15 nm before threshold exposed mainly to approach noise has had its exposure reduced by about 2 NNI relative to 1972 solely as a result of the present level of use of the procedures. However, if it is assumed that up to 90% incidence of CDA and LP/LD is achievable, accompanied by a further small increase in the noise benefits of the LP/LD and CDA procedures, then there is potential for doubling the reduction in NNI being achieved at present.

5.2.6 At first sight Figure 4 might appear to underestimate the effects of the benefits shown in Figure 2 occurring with the incidences quoted in section 5.2.3. The explanation lies in the fact that NNI reduces as $\bar{L}$ and $\bar{L}$ is the <u>logarithmic</u> mean peak noise level. Thus any procedure which yielded say a noise benefit of 10 dB with an incidence of 50% would not produce a 5 dB decrease in $\bar{L}$ but only about 2.6 dB due to the effect of logarithmic averaging (see Figure 3). This feature illustrates what might be termed a "law of increasing returns". As incidences increase towards 100% the NNI reduction per unit increment in incidence becomes increasingly greater, which underlines the value of inducing the highest possible incidence.

6 CONCLUSIONS

6.1 Data obtained from two sets of measurements and observations in 1976 and 1977 coupled with some reasonable inference have allowed the noise benefits associated with the LP/LD and CDA procedures, the areas over which the benefits apply and the incidence of each procedure, to be estimated for westerly approaches at Heathrow.

6.2 The noise benefit resulting from the use of LP/LD procedures is 3dB. This is an average value for all aircraft types and for all degrees of application of the procedure. It means that on any single approach when the procedure is used, the peak noise level directly beneath the approach path is reduced on average by 3dB relative to the typical traditional approach procedure. This benefit can be obtained in an area lying between about 5 and 11 nm before threshold but the actual area is dependent on the extent to which the procedure is sustained towards touchdown.

6.3 Expressed in a similar fashion the CDA benefit is 4dB at about 9 nm from threshold increasing to 9dB at 15 nm. The benefits of both CDA and LP/LD and the areas over which they apply are illustrated in Figure 2 and it should be noted that the distances from threshold quoted above are aircraft track distances and not necessarily along the extended centre line.

6.4 Although benefits have been expressed above as the reduction in peak noise level directly beneath the aircraft flight path, all or part of these benefits are obtained wherever the aircraft is heard within the area of application of the procedure. The whole of the LP/LD benefit of 3dB is obtained at all lateral distances but there will be some diminution of CDA benefit with increase in lateral distance. However, the CDA benefit will not be less than 4 dB at any lateral distance.

6.5 The noise benefits of the separate procedures are roughly additive where their areas of application overlap.

6.6 In March 1977, CDA was observed to be used on 54% of all approaches. Similarly, the incidence of LP/LD was 68% at 8.7 nm from threshold but this had fallen to 39% at 6.5 nm with possibly a relatively small percentage of approaches sustaining the procedure to the maximum.

6.7 Between any two years the reduction in noise exposure (NNI) as a result of the procedures depends on the value of the noise benefits and the proportion of approaches using them in those two years. Relative to 1972 there was improvement during the trials everywhere between 5 and 15 nm before threshold on westerly approaches where NNI is not dominated by the noise from easterly take-offs. Although the reduction is variable, as shown in Figure 4, it can be stated that the greater part of this area experiences a reduction in noise exposure of about 2 NNI relative to 1972.

6.8 There are indications, both theoretical and experimental, that the average noise benefits of LP/LD and CDA procedures quoted above are less than those which might be achieved with increased experience, more education of some operators and an ability on the part of ATC to allow a speed of 170 knots when required down to about 1500 ft above threshold. These factors could reasonably be expected to lead also to fuller exploitation of the procedures with the potential of perhaps doubling the noise exposure benefit reported above.

6.9 The conclusions so far have been confined to noise benefits but the DORA study also concerned operational matters. This aspect of the study indicated no change in the safety with which traffic was being controlled or in runway capacity but suggested that substantial fuel saving was being achieved.

REFERENCES:

1 A Technical Evaluation of Initial Trials of Quieter Approach Procedures at London (Heathrow) Airport - Summary Report

CAA Paper No 78002 - February 1978 Price: £2.50.

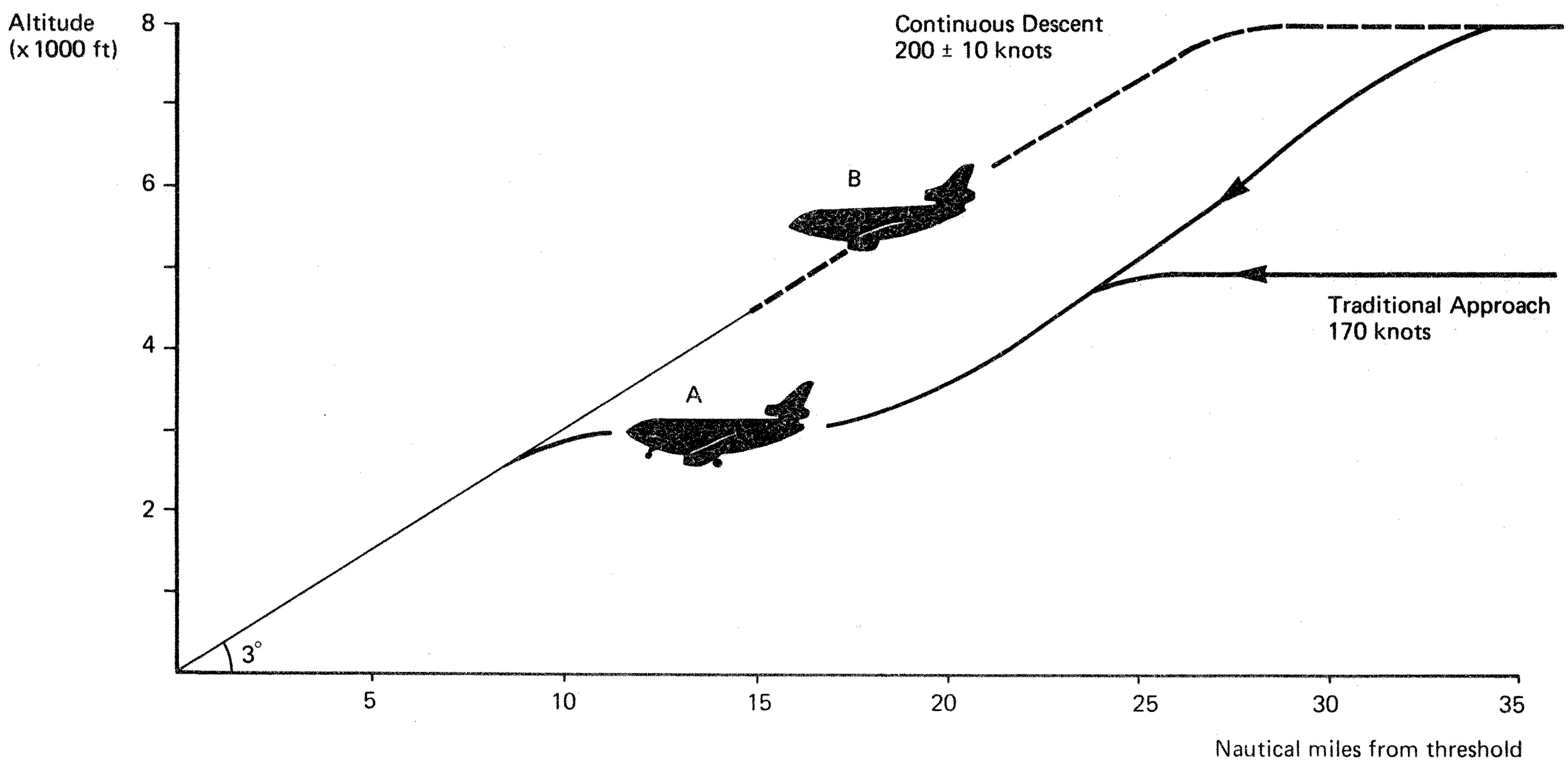


Fig 1 Traditional and continuous descent approach profiles

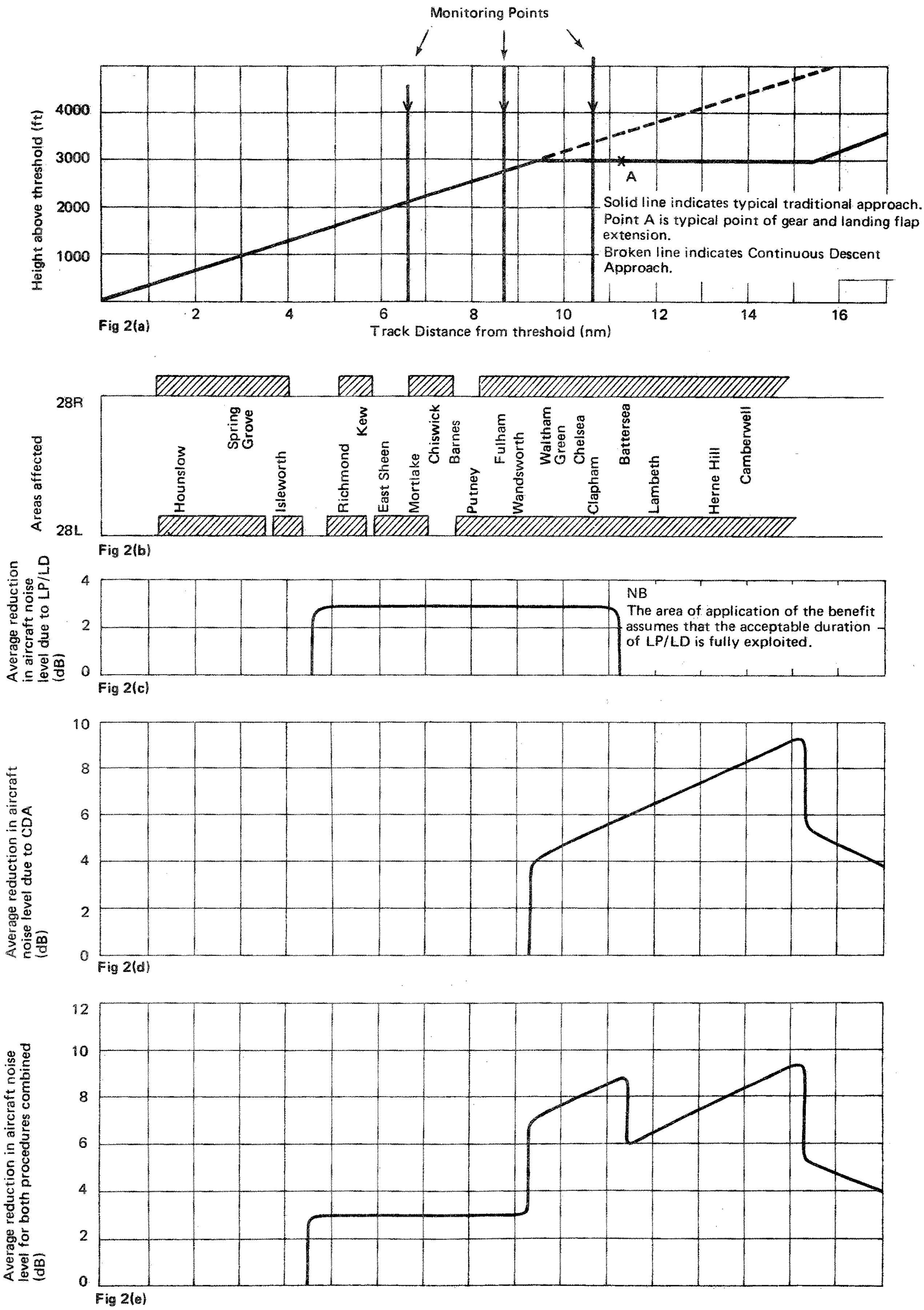
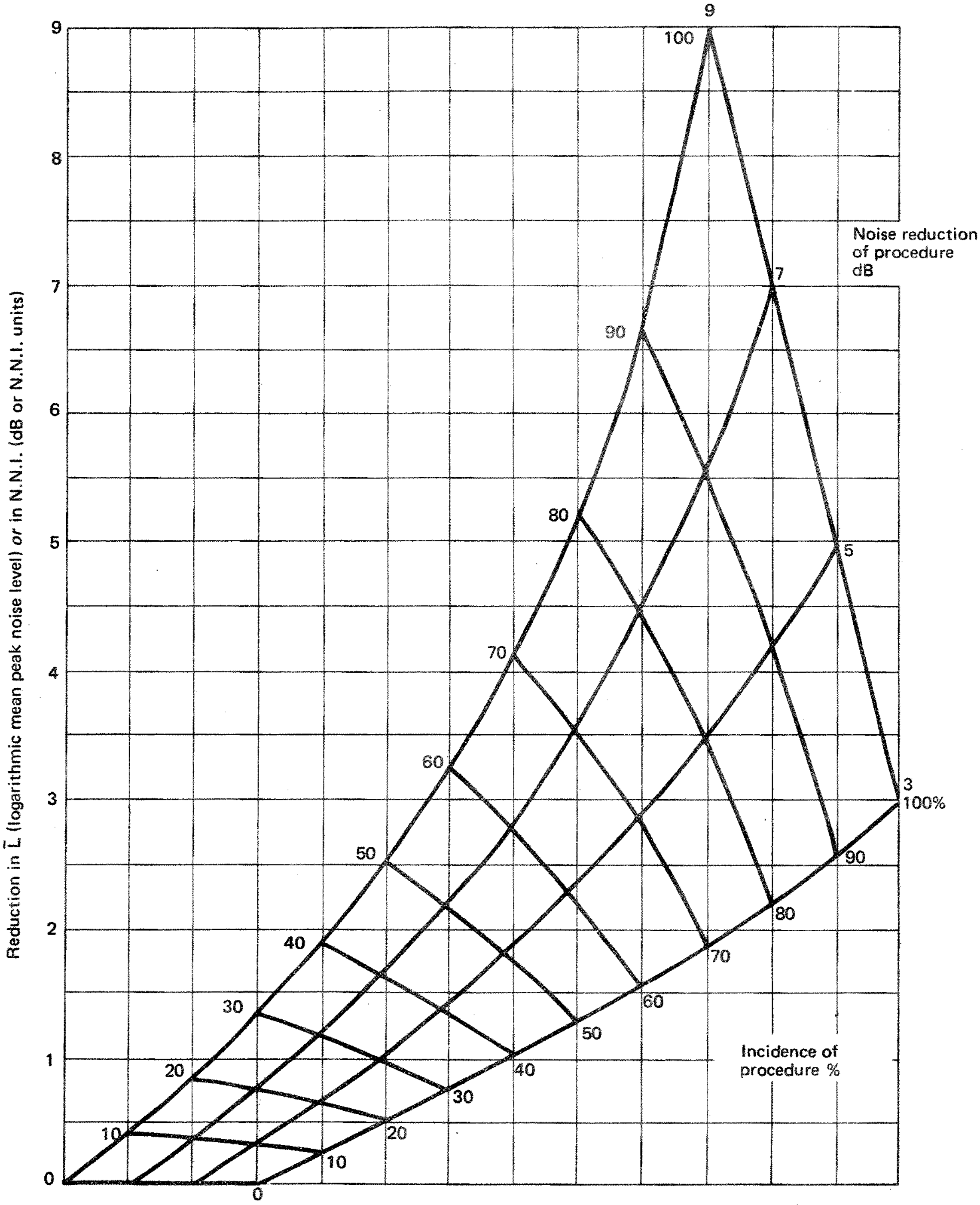


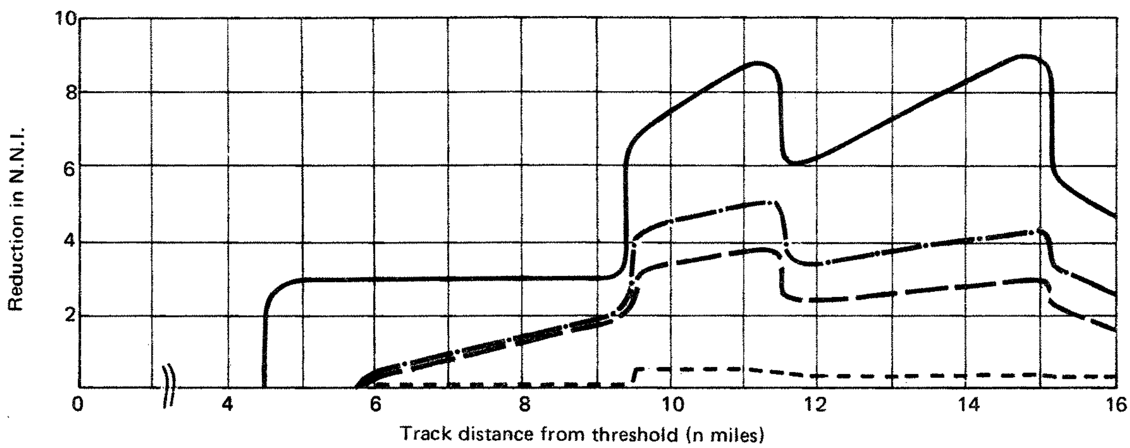
Fig 2 Average noise benefits resulting from LP/LD and CDA procedures for a single westerly approach at Heathrow

NB All reduction in aircraft noise level shown are those directly below the flight path.



N.B. These curves assume that the incidence of the procedure is uniform across the traffic mix

Fig 3 Reduction in $\bar{L}$ or N.N.I. resulting from the noise reduction of a procedure for a given incidence of that procedure (carpet plot)



KEY:

100% incidence of CDA and LP/LD

70% incidence of CDA and observed LP/LD

54% incidence of CDA and observed LP/LD (DORA Study results 1977)

Incidence of both procedures at or prior to 1972

Fig 4 Reduction in N.N.I. under the flight path (idealized)

APPENDIX

TABLE A1 DESCRIPTIVE STATISTICS OF THE PEAK NOISE LEVELS IN FOUR CLASSES OF APPROACH - 1976 AND 1977 DATA

Position	Class	Runway 28R			Runway 28L			Both runways combined		
		Arithmetic mean dBA	Standard deviation dBA	Sample size	Arithmetic mean dBA	Standard deviation dBA	Sample size	Arithmetic mean dBA	Standard deviation dBA	Sample size
Outer Monitoring Point 10.6 nm from threshold	Class 1 CDA and LP/LD				69.6	4.7	48	69.6	4.7	48
	Class 2 CDA and not LP/LD				72.7	5.4	5	72.7	5.4	5
	Class 3 Not CDA and LP/LD				75.0	6.5	38	75.0	6.5	38
	Class 4 Not CDA and not LP/LD				80.3	3.8	5	80.3	3.8	5
Middle Monitoring Point 8.7 nm from threshold	Class 1	73.6	5.4	155	70.6	5.2	123	72.3	5.5	278
	Class 2	75.8	5.9	93	73.3	5.6	63	74.8	5.9	156
	Class 3	75.4	5.4	56	74.8	7.6	17	75.2	5.9	73
	Class 4	79.1	4.7	27	71.9	6.1	11	77.0	6.0	38
Inner Monitoring Point 6.5 nm from threshold	Class 1	74.5	4.5	127	73.8	5.3	91	74.2	4.9	218
	Class 2	77.1	5.1	260	76.5	5.2	137	76.9	5.2	397
	Class 3	72.0	-	1	77.0	6.8	8	76.5	6.5	9
	Class 4	78.6	4.7	10	79.5	5.0	7	79.0	4.7	17

TABLE A2 ESTIMATES OF THE NOISE BENEFITS RESULTING FROM LP/LD AND CDA PROCEDURES DERIVED FROM THE COMBINED 1976 AND 1977 RESULTS SHOWN IN TABLE A1

Position	Procedure	Estimated noise benefit dB (2)	Source of estimate
Outer Monitoring Point 10.6 nm from threshold	CDA	5.4 (3)	Class 3 - Class 1
Middle Monitoring Point 8.7 nm from threshold	CDA (1)	1.6 (3)	Class 3 - Class 1(28R)
		4.6 (3)	Class 3 - Class 1(28L)
	LP/LD (1)	2.2	Class 2(28R) - Class 1(28R)
		2.7	Class 2(28L) - Class 1(28L)
Inner Monitoring Point 6.5 nm from threshold	LP/LD	2.7	Class 2 - Class 1

NOTES (1) An estimate for each runway is made at the middle monitoring point as there are significant statistical differences between the distributions of Class 1 and Class 2 on different runways. For Class 3 the combined distribution is used.

(2) These estimates are all significant at the 0.025 level

(3) CDA total benefit