EIGHTEENTH EUROPEAN ROTORCRAFT FORUM

SP - 02

Paper No 502

HELICOPTER NOISE CERTIFICATION
PAST - PRESENT - FUTURE

EurIng JOHN LEVERTON PhD, MOA, MRAeS
E.H. INDUSTRIES INC.

September 15-18, 1992

AVIGNON, FRANCE

HELICOPTER NOISE CERTIFICATION: PAST-PRESENT-FUTURE

EURING JOHN W. LEVERTON[1]
E.H. INDUSTRIES INC.
ARLINGTON, VA, U.S.A.

PREFACE

This paper reviews the historical development of Helicopter Noise Certification rules. The issues highlighted are those to which particular attention has been given over the years.

The manufacturers are represented within ICAO by ICCAIA who have Observer status. ICCAIA consists of the Aerospace Industries Association of America Inc. (AIA), Air Industries Association of Canada (AIAC), Association Europeene des Constructeurs de Material Aerospatial (AECMA) and The Society of Japanese Aerospace Companies. AIA, which represents the manufacturers in the United States [Bell Helicopter Textron, Boeing Helicopters, Sikorsky and McDonnell Douglas Helicopter] and AECMA of Europe [Agusta, Aerospatiale (now EURCOPTER-France), MBB (now EUROCOPTER-Deutschland) and Westland Helicopters] are the only two active groups.

1. INTRODUCTION

Noise Certification standards for subsonic jets were adopted by the International Civil Aviation Organization (ICAO) following the first meeting of the *Committee or Aircraft Noise* (CAN1) in 1972. Noise certification for light propeller-driven aeroplanes followed in 1974 (CAN3) and further standards for propeller-driven aeroplanes, STOL aeroplanes, and installed APUs in 1977 (CAN4). During the mid-1970s consideration was given by ICAO to the noise from helicopters and the first noise certification standards were agreed at CAN6 held in 1979.

ICAO issues *Standards and Recommended Practices (SARPS)* which do not in themselves constitute national or international rules. ICAO adopted a resolution in 1948 drawing the attenuation of ***'Contracting States'*** (nations) *"to the desirability of using in their own national regulations, as far as practical, the precise language of those ICAO Standards that are of a regulatory character . . "*. In addition there is an obligation on ***Contracting States*** to notify ICAO of any differences between their national regulations and practices and the International Standards contained in the ICAO Annexes. The majority of the world nations, including the USA, Canada and all the major European nations, are active members of ICAO and have been party to the development of the ICAO Standards for the noise certification of helicopters. Thus it would be expected that noise certification rules issued by the USA, United Kingdom, and France - which set the standards followed by many other nations in the world - would be identical. This is not the case and significant technical and other differences have existed, and still exist, between the helicopter noise certification standards applied in the USA (and within nations which follow USA/FAA practice), and those generally used in Europe which, except for minor differences, all follow ICAO Annex 16.

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[1]ICCAIA Representative (Helicopters) to ICAO

2. CAN6 STANDARDS

2.1 Scope

When helicopters were considered it was agreed that a single rule would be applied to all helicopters irrespective of the design weight, number of rotors, number of engines etc. and that, as in the case of other ICAO Annex 16 standards, test data should be corrected to a specific set of conditions and flight procedures. **The final helicopter standards were issued as Chapter 8 with the corresponding evaluation procedures in Appendix 4** (1) with an applicability date of 26 Nov. 1981.

2.2 Test Conditions

The CAN6 standards related to three test flight conditions - **flyover, approach** (landing) and **take-off**. During the initial discussion on how to develop standards which were *economically reasonable and technically feasible*, largely driven by the aim to keep the tests simple and the costs low, procedures based solely on **flyover** and **hover** were considered. *This is of interest* since it is these two conditions which essentially set the *design parameters*, such as rotor size (radius/chord), number of blades, tip speed, etc., of a helicopter. The technical problems with *hover tests* proved unsolvable and *hover* was dropped as a possible test procedure. There was a major interest in not only controlling the noise at source, but also measuring the noise in regimes of flights appropriate to operations and as a result **approach** (landing) and **take-off** condition were added.

It was agreed that the **flyover** should be a *straight and level* flyover test. The main debate related to the choice of altitude: it was felt that due to the low sound generated by helicopters, particularly smaller helicopters, that to ensure sufficient *signal (helicopter sound)-to-background noise*, that the flyover height should be 150m (500ft). This test procedure is illustrated in Figure 1(a).

The development of the **approach** requirements provoked considerable debate, since firstly helicopters tend to generate impulsive noise in descent - commonly known at that time as *Blade Slap* or *Blade Bang* and now more often referred to as *BVI or Blade Vortex Interaction noise* - and secondly helicopters do not tend to fly a constant slope/speed on approach. After considerable debate a 6° approach at Vy (best rate of climb speed) was chosen with a reference flyover height of 120m (394ft): as illustrated in Figure 1(b).

Defining a **take-off** procedure presented a problem in that, depending on the helicopter performance, wind speed, etc. the height above any measuring position fixed relative to the take-off point, varies considerably. In addition since it is necessary to correct the data to a specific **reference procedure**, long debates on the best solution took place within the ICAO Working Group. Finally use of a *artificial reference procedure*, where the helicopter is assumed to fly straight and level at 20m (65ft) and then climb at Vy with maximum take-off power from a point 500m prior to the microphone array was agreed: this is illustrated in Figure 1(c). The maximum correction was set at 4EPNdB which effectively put a limit on the *height above the microphone*. Some of the industry would have preferred a *real take-off* since it would more fully represent what occurs in practice and give benefit to helicopters with high performance/acceleration, even so it was generally agreed to be an acceptable compromise.

2.3 No Correction Window

The CAN6 standards only required mandatory corrections to the measured noise data if test conditions were outside a number of specific *test windows* (Reference 1: Appendix 4 Para 9.1.2). By implication, of course, corrections could be made by the applicant conducting certification, if he so desired, even if tested within the *window*. In addition a requirement that the tests should be carried out under conditions where the sound attenuation rate was not greater than 12dB/100m in the 8kHz one-third octave band (Reference 1: Appendix 4, Para 2.2.2) eliminated testing in the low humidity/low temperature range as indicated in Figure 2 which shows the reference temperature and humidity. The *no correction window* was considered by all involved to be a significant aspect since it allowed the costs and analysis to be minimized.

2.4 Microphone Array

Somewhat related to the selection of the *no correction window*, which allowed tests to be conducted with ±10m (33ft) vertically and ±5° from the zenith of the reference flight path, was the number of microphones to be used. Following an examination by a number of nations it was agreed prior to CAN6, that to overcome the necessity to make detailed emission/source analysis adjustments and **cover small *off track* variability**, that rather than a single microphone under the flight path 2 additional sideline microphones at ±150m (±492ft) would be required (Figure 1).

2.5 Noise Unit

Industry at that time did not favor the EPNdB or Effective Perceived Noise Level, later written as EPNL, since traditionally helicopter noise had been measured/rated in terms of dBA (A weighted sound pressure levels). Light propeller-driven aeroplane standards (ICAO Chapter 6) was based on the maximum dBA value but all other ICAO standards, including the heavy propeller-driven aeroplane rule (Chapter 5), were in terms of EPNdB. It was stated by a number of members that it was essential to have a unit which handled 'tone corrections', since helicopters generate tones, and took account of the duration of the sound. This, combined with higher weight range covered by the then proposed helicopter rule than associated with *'light props'*, lead to the choice of the **EPNdB/EPNL**. Some industry members felt that the tone correction was inappropriate to rating multi-tonal helicopter noise since it was essentially developed to handle single tones akin to those generated by jet engines and propellers. There was also some concern that maybe the unit did not fully account for the impulsiveness of helicopter noise. There was some mixed views on these aspects and at the time these issues were considered secondary to the choice of test procedure and, more importantly, the noise limits.

2.6 Noise Limits

The main debate within the ICAO Working Group, and ICCAIA, was on the choice of noise limits for the three conditions. The available data was based largely on the results of *pseudo certification exercises* conducted in the USA, France and the United Kingdom. This data had not been fully tested and/or analyzed to the proposed *regulatory format* but it was generally agreed this was adequate for setting, for what became known as, the *CAN6 noise limits*. Industry's concern was not only related to the procedure being used to derive the limit, but also the *EPNdB/weight* or more strictly the *EPNdB/mass* relation being proposed for the majority of the weight range of interests.

The large propeller driven aircraft (Chapter 5) had *weight (mass) dependency*, depending on the flight condition/reference, of 2EPNdB per doubling of mass for the lateral and approach and 5EPNdB per doubling for flyover. Subsonic jet aeroplanes (Chapter 2 and Chapter 3) had values per doubling of mass of 3 and 4 EPNdB depending on the number of engines/conditions etc. When the helicopter data was examined it was difficult to fit a well defined relation: this can be appreciated from Figure 3 which shows the flyover data plotted to a log mass (weight) basis. Finally after considerable debate 3dB per halving of mass from an upper mass of 80,000Kg (176,368lb) was agreed. This was in contrast to the three *helicopter noise prediction methods* available at that time which indicated a mass or thrust squared relationship, or in other words, *a 6dB per doubling or halving of mass*.

When the process to determine the noise limits was originally debated, only the results for two flight procedures, approach and flyover were available. Subsequent take-off data became available but not all of it was collected under the test procedure finally selected for this condition. As the debate proceeded many favored a single noise limit for all three conditions: it was argued this could be achieved by suitable choice of overhead test height. This, however, did not prove practical for a mixture of technical and political reasons and was abandoned.

The final limits, for the three conditions, were chosen by the ICAO Working Group by first establishing an *agreed* mean regression line incorporating the 3dB/doubling of weight or 9.96logW relationship. The next stage for developing the limits for *new designs* was an estimate of what would happen in the future: here reference was made to data for the Sikorsky S61 since it was considered to represent the best noise levels which had been achieved and which were likely to be obtained in the near future. As a result of this the limits were decreased by 1.7dB for approach, 1.3dB for take-off and 1.4dB for flyover to give what the Working Group termed the *projected mean noise levels*. Then, to account for uncertainties in prediction and determination of the noise levels of a specific design, the levels were <u>increased</u> by 2EPNdB for approach and take-off and, to account for increasing flight speed of future helicopters, 3EPNdB for flyover. In this context it should be remembered that most of the noise test data had to be determined from relatively low speed helicopters and evidence was available that the newer faster helicopters typically generated 2-3dB high noise levels: thus the additional 1dB was considered a reasonable adjustment. Finally to place *pressure on designs across the board* the levels for each flight conditions were decreased by 1dB to give the CAN6 limits shown in Figure 4.[2] In this analysis it is of interest to note that the ICAO Working Group appreciated the uncertainties with prediction and measurement and allowed a 2EPNdB band to allow for this aspect. The Working Group also proposed the values should be independent of weight above 80,000Kg (176,368lb) and below a weight defined in terms of specific EPNdB value which implied that the levels were constant below 788Kg (1737lb).

The manufacturers suggested that not only was the limits more demanding in the case of medium and high weight ranges, but they should be -3dB higher than suggested by the Working Group. The manufacturers also proposed that in the case of derived versions of older designs the limit should be *'no noisier than the parent + 2EPNdB'* but this did not receive any support.

The regulations also provided a degree of *trade off* enabling the noise limits to be exceeded by a single point by up to 3EPNdB and a total of 4EPNdB providing the excess(s) were offset by the level in the other condition(s). This follows the approach adopted for 'fixed wing aeroplanes' and takes account of the variation in noise level between different designs. To cater for helicopters, whose levels were above the proposed limit, a provision was added which allowed derived versions of these helicopters to be certificated providing the noise level was not higher than that of the parent.

2.7 Applicability

The Working Group proposed that the new Chapter 8, including the associated noise limits, should apply to *new designs* whose application was made on or after 1 January 1980 and for change of design applications (*derived versions*) on or after 1 January 1985 and this was approved at CAN6.

3. OPPOSITION TO CAN6/FAA NPRM

When industry finally realized they had a noise certification rule to meet discussions were elevated to a high level in most companies because of the cost and the implication on sales. Up until CAN6 the development of certification standards, quite rightly because of its largely technical nature, had been handled by the acoustic/ noise engineers and many in higher management appeared to be caught by surprise when CAN6, or rather ICAO Annex 6 Chapter 8 was issued. This was brought sharply into focus when the FAA issued NPRM (Notice of Proposed Rule Making) 79-13 on July 9, 1979. This not only picked up the CAN6 noise limits and test procedures but covered future production of all helicopters. Several high level international meetings were held between the industry and with the appropriate government agencies. Not only was there a problem perceived in meeting the CAN6 noise limits with some existing helicopters, but *total helicopter noise* could not be predicted with any real accuracy and thus large design margins, to have a reasonable (90%) probability of noise certification, were required. In this context it should be noted that the ICAO CAN6 standards covered both new designs (prototypes for which an application of a certificate of airworthiness had been made) and derived versions (existing helicopter for which an application for a change in

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[2]This figure also shows the CAN7 limits (subsequently agreed by ICAO in 1983) and the CAEP1 data base.

type design had been made). Derived versions are the backbone of the helicopter industry and most companies were faced with the position of having to consider the certification of the next derived version of a helicopter designed in many cases, without specific reference to noise limits of the type embodied in ICAO Annex 16. Furthermore, with one or two exceptions, no truly new design helicopters were envisaged by any manufacturer. In addition the U.S. rules proposed in NPRM 79-13 would have extended the ICAO CAN6 procedures/limits to the future production of all helicopters.

The situation was further compounded by the unstable world conditions in the early 1980s, particularly the 'oil market' which supported directly or indirectly much of the civil helicopter industry, and the corresponding *down turn* of the industry in general which meant that many new projects were being put on hold or abandoned.

Once the economic impact of the CAN6 standards had been fully appreciated by authorities of the major nations, there was a general agreement that on hindsight, the limits had been set too low. In addition, as a result of this debate on the economic impact and the opposition to the CAN6 limits, the introduction of the ICAO Annex 16 Chapter 8 rules was delayed in most nations. A major exception was France who introduced the rules in 1980: they were, however, subsequently amended to reflect the CAN7 changes. Austria adopted the CAN6 limits in 1982 and these are still applied: similarly Switzerland in late 1983 introduced ICAO Annex 16 Chapter 8 with CAN6 limits together with some 'operational constraints'.

4. CAN7

4.1 Formal Change of Limits

At CAN7 the main debate was related to the change of limits but by the time of the meeting this was essentially a matter of agreeing, internationally, the new limits. To relieve the economic burden applied by the CAN6 rule a number of nations proposed that the limits for new designs and derived versions should be raised by 3EPNdB per condition. The USA, in addition, expressed the view that the noise limits of 'derived versions' of older designs and non-civil prototypes should be raised a further 2EPNdB (5EPNdB in total) and, although some other nations were sympathetic towards these views they were not generally supported. The discussion of these issues were further complicated by difficulty of defining a *derived version* and in particular a *derived version of a military parent*. After a long discussion it was finally agreed, but only by a small majority, that the limits should be increased. As a result the limits were raised across the board by 3EPNdB (CAN7 limits) as indicated on Figure 4. The date of applicability for new designs was also changed and made to coincide with that of 1 January 1985 set by CAN6 for derived versions (2). The *no noisier than the parent* provision for derived versions of CAN6 was removed from the CAN7 rules on the grounds that the 3EPdB increase adequately covered such helicopters.

It should be recognized that even though the changes to raise the limits was fully agreed within ICAO, many individuals and a number of member states, did not agree and felt that the CAN6 limits should have been retained. Some of these, no longer directly involved with this issue have expressed publicly the view that the helicopter limits are too high and should be at CAN6 value or lower.

4.2 Source Noise Correction

A number of nations suggested that since the noise of a helicopter is very dependent on the main rotor (and tail rotor) characteristics and it is known that the noise from the rotor is dependent on the *advancing tip Mach. Number* corrections to account for 'off reference conditions' should be applied. This requirement for a *noise source correction* became a major issue of contention since it can increase the *flyover testing* by a factor of 4 to 5 and overall certification cost by 30 to 40%. Industry was not against the concept from a fundamental point of view since in some cases it may be desirable but it appeared to be questionable if the then suggested method of using a *sensitivity curve of EPNL versus airspeed* would show a marked improvement in accuracy. The wording finally agreed at CAN7, however, only required corrections to be applied if the average test airspeed differed from the referenced airspeed by more than 4km/hr (2.2Kts). This could be achieved by conducting tests in two directions and source noise correction were only mandatory if outside the defined limit.

4.3 Other Changes

A number of other issues were debated within the ICAO Working Group and subsequently agreed at CAN7. The first related to the flyover test speed: at CAN6 it was agreed this should be at $0.9V_H$ or $0.9V_{NE}$ *whichever is the lesser*. It was pointed out that many of the new helicopters were being developed with higher V_H and/or V_{NE}, but these speeds would not be used for *low level flying* such as over cities at 500ft to 1000ft. It was agreed to change the $0.9V_H$ requirements to $0.45V_H$ + 120km/h ($0.45V_H$ + 65knots) [a corresponding change was also made to that for $0.9V_{NE}$]. Thus a helicopter with 160Kts V_H would be tested at 137Kts rather than 144 knots. ICCAIA would have preferred to see a upper test limit of 130 knots since it was felt that this was the maximum likely to be used at low levels over built-up areas, but felt the Working Group proposal, subsequently approved at CAN7, was reasonable.

As a result of testing within a number of nations, it was also agreed to increase the 'zenith' requirement of ±5° to ±10°. It was generally agreed this would overcome some of the testing difficulties and hence expense and **not effect the overall accuracy.** Some other minor changes were also made.

4.4 Adoption of CAN7 Standards

After CAN7 it had been expected that most nations would quickly pick up CAN7 standards and embody them in their national rules. This was not the case, mainly due to lack of need, complexities with national regulatory procedures, etc. France amended its rule from CAN6 to CAN7 limits but retained the CAN6 applicability dates, Switzerland, as mentioned previously, adopted CAN6 on 1 Jan. 1984 and Australia and The Netherlands introduced CAN7 in 1984 and 1985 respectively. The UK, on the other hand, did not follow until 1986. Similarly the U.S. did not start its process until it issued a second NPRM in March 1986 and it was late 1988 before it became a rule. Germany and Canada delayed the introduction of their rules until after CAEP1 and many other nations, including Japan and Italy, have not introduced any helicopter noise certification rules to date.

5. AFTER CAN7 - HNMRP

5.1 The Need

After CAN7 the manufacturers felt that ICAO Annex 16 Chapter 8 was a fair compromise which industry could *'work with'*. It also felt that nations that had adopted CAN6 would amend their rules and the other nations who had been holding off introducing noise certification would adopt CAN7 after the appropriate ICAO review process which implied an applicable date for the new rules of 1 January 1985. Once this was done it was expected there would be little change until experience had been gained with the application of the CAN7 Chapter 8 of ICAO Annex 16 (2).

The ICAO Working Group, however, decided due to concern over the variability in noise levels highlighted as a part of the debate over the noise limits and issues raised at CAN7, to conduct a *Helicopter Noise Measurement Repeatability Program* (HNMRP). The aim was to establish the repeatability of noise certification levels and to improve, where necessary, the test and analysis procedures. This was a worthwhile effort and fully supported by ICCAIA. It lead, however, to many changes which increased the cost and complexity of the ICAO standards. In addition a number of issues raised in the report which were **not** adopted by ICAO at the subsequent CAEP1 meeting were later embodied in the FAA noise certification rule (FAR Part 36 Appendix H) and as result this lead to differences between the standards applied in the USA and by the majority of other nations.

5.2. HNMRP: Program

Nine nations were involved in the HNMRP (Australia, Brazil, Canada, France, Germany, Italy, Japan, United Kingdom and United States of America) with 6 groups conducting actual tests (Australia, Brazil, Japan, Canada-United States, Germany-United Kingdom and France-Italy-United States). Six helicopter manufacturers (Aerospatiale, Agusta, Bell Textron, Kawaski, Sikorsky and Westland) participated and in all 529 flight tests which were made using a Bell 206L-1 or the acoustically equivalent 206L-3 Long Ranger.

5.3 Results

The data, as can be imagined due to the large number of organizations involved, was very complex. As a result of the HNMRP a number of major changes to Chapter 8 were agreed by the Working Group and proposed to CAEP1. It is worth noting, however, that even the CAEP1 report (3) indicates there was still disagreement on the *interpretation and significance of the HNMRP results, as well as, a lack of understanding of the statistical methods used in the analysis process*.

5.4 Atmospheric Absorption Layer Proposal

It was proposed to the Working Group that consideration be given to use of a atmospheric absorption laying technique based on measurements at 10m (as CAN7) and at the helicopter height. Initially it was proposed this would only involve the temperature differences so that OAT (Outside Air Temperature) measured on the helicopter could be used. This was later changed to include humidity and it was generally agreed measurements on the helicopter would not be sufficiently accurate. Thus this proposal effectively required use of a weather balloon. This was not supported by the majority of the ICAO Working Group and as a result was not submitted to CAEP1 as a recommendation. Even so the United States (FAA) subsequently included such a requirement in their noise rule.

6. CAEP1: MAIN ISSUES

6.1 'No Correction Window' Removed

The proposal to delete the 'no correction window', developed at CAN6 and not at CAN7, based on HNMRP test data and experience, was made prior to CAEP1 at a HNMRP meeting in Paris in April 1986 (4).

This was not supported by ICCAIA but at CAEP1 the *no correction window* was deleted from the rule and mandatory corrections introduced. This one change dramatically increased the cost and complexity of Chapter 8 and ignored the fact that these sort of variations used to justify the change were accepted by CAN6 by the choice of 3 microphones etc. and when developing the noise limits. The debate in CAEP1 was, however, fairly intense and it was not only the manufacturers who were unhappy with the deletion of the *no correction window*, since a number of members (national representatives) argued for its retention (3).

6.2 Mandatory Source Noise Correction

The HNMRP focussed much of its attention on the *Source Noise Correction* and suggested that considerable improvement in repeatability could be made if noise sensitivity curves, based on PNLTM *versus advancing blade tip Mach Number*, were used. ICCAIA considered the procedure questionable, particularly when weighed against the fact it dramatically increased the flyover test requirements. It was industry's view that no corrections should be applied if tests were conducted within a test window and if outside the window, since the noise characteristics will be helicopter specific, any correction procedures should be agreed between the applicant and certificating authority. Also the correction is *negative* if the temperature is ISA + 10° (25°/77°F) or less. None of the arguments had much impact and the source noise correction, based *normally* on PNLTM versus advancing blade tip Mach number, was made mandatory (5).

6.3 Take-Off Profile

Wind speed tends to increase with height and as a result the helicopter will tend to climb much more rapidly then in a zero wind case. As a result, as illustrated in Figure 5a, so that the height above the microphone array can be much larger than the reference. Similarly in the zero wind case the profile can be significantly below the reference profile (Figure 5a). As a result the corrections can exceed the limit defined in Annex 16 in terms of EPNdB. At CAN6 this limit for take-off was fixed at 4.0 EPNdB.[3] It was reported to CAEP1 that difficulties had been experienced in meeting this requirement and to overcome this and allow the heights to be made closer to the reference value, it was agreed to change the wording to allow *"the position of point B to vary within the limits allowed by the certificating authorities"*. This is illustrated in Figure 5b where a position has been choose such that the take-off profile actually passes through the reference height. This change was supported by ICCAIA and, if the CAN6 *no correction window* had not been deleted, would have allowed the *±10m (±33ft) requirement* to be met. Changes were also made to the *total adjustment limit* so that in the 4.0EPNdB limit the arithmetic sum of Delta 1 and the term -7.5Log (QK/QrKr) from Delta 2 must not exceed 2.0EPNdB (5).

6.4 Applicability

At CAEP1 changes were made to Chapter 8 Applicability [Para 8.1.1.b)] (5): CAN7 only required noise tests of derived versions (application for a change of type design) when there was a *significant effect on the noise*. This phase was removed so that noise certification associated with all applications for a change of type design was required. This created a tightening of the ICAO requirements which was not immediately recognized.

6.5 Alternative Approach Procedures

ICCAIA, from the time of the adoption of the 6°/Vy approach condition at CAN6, stated that this treated helicopters unfairly since the level generated during this condition was helicopter model dependent. This is because the level of impulsive noise (*BVI/Blade Slap*), which dominates the overall level on most helicopters on approach, varies from helicopter to helicopter. This is illustrated in Figure 6, reproduced from a paper submitted to ICAO in 1985 (6), which show plots of RoD versus airspeed with the *impulsive noise boundaries* indicated for the B105 and Bell 206A together with the 6°/Vy test point. As can be seen at this condition some helicopters are in a state of intense BVI, while on others it is minimal. ICCAIA proposed that an *alternate approach procedure*, made at any combination of airspeeds including deceleration airspeeds and variable angles, should be allowed. For evaluation with the noise limit corrections could be made back to the 6° reference. This concept is illustrated diagramtically in Figure 7. Various ideas were presented and discussed including allowing the tests to be conducted within a 4° to 10° window. It was also suggested that even if a *variable approach* could not be accepted, then may be it could be combined with the '6°/Vy approach' so that the certificated level would be the average of the two results. Noise test data from tests conducted jointly by FAA/HAI indicate the reductions, relative to 6°/Vy, of up to 6.9dB in SEL units under the flight path, could be obtained (7). Some members suggested that, rather than allowing complete flexibility, tests should be conducted at Vy with approach angles of 3°, 6° and 9° and that the levels should be averaged. Even though the details of the correction procedure etc. was not fully defined, this gained general support within the Working Group. It was subsequently suggested that rather then allowing it as an alternate procedure to the existing 6°/Vy requirement it should

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[3]For Flyover and Approach this is 2EPNdB and this has not been changed.

be *guidance material* so that 'experience' could be gained with its use. This was agreed at CAEP1 and the 3°, 6° and 9° measurement procedure was incorporated in ICAO Annex 16 as **Attachment D (5).**

6.6 Need for Simplification

At the time of CAEP1 (1986) ICCAIA estimated that compliance with Chapter 8 would be between $200,000 and $300,000 for helicopters which sell at prices from $50,000 to $6 million. This compared with an estimate of $500,000 for noise certification under Chapter 3 of fixed-wing aircraft selling at $50 million. ICCAIA stated that not only was the burden too high, it was markedly out of balance in the case of small/light helicopters. Most states at CAEP1 appreciated this and in the terms of reference for future work set the initiated steps for the development of a *light helicopter rule*. The manufacturers strongly welcomed this but also felt that attempts to further simplify Chapter 8 should continue.

7. FAA RULE

7.1 NPRM: March 1986

In March 1986, three months prior to CAEP1, the FAA issued its second notice of proposed rule making: NPRM 86-3. Technically the proposed FAA rule was not greatly different from that of CAN7 or that being discussed within the ICAO Working Groups. It did, however, unlike CAN7, include reference to Stage 1 and Stage 2 helicopters/noise limits. The Stage 2 limit was effectively the same as ICAO CAN7 noise limits and Stage 1 applied to helicopters which did or had not been shown to meet the Stage 2 limit. Stage 1 noise limits for *acoustical changes* was defined such at a Stage 1 with a noise level exceeding 'Stage 2 + 2EPNdB' may not, after change of type design, exceed the original level (ie. be no noisier than the parent). Stage 1 helicopters with a level below the 'Stage 2 + 2EPNdB' limit could increase up to that level after a change of type design. This, from a manufacturer's point of view, was in line with previous proposals and was not seen as a major difficulty since 'Stage 2' levels corresponded to those of CAN7 and the test conditions etc. were identical or similar to those of ICAO Annex 6 Chapter 8/Appendix 4.

7.2 Final Rule

When the final rule, FAR Part 36 Appendix H (8), was issued in February 1988, (18 months after CAEP1), it contained a number of differences from ICAO Annex 16. The major ones were a requirement which implied a maximum wind speed limit, at the flyover height of 500ft/150m, of 10 knots and a requirement to use the averaged temperature and relative humidity values at 10m *and the aircraft altitude*. The first of these puts a major restriction on testing relative to the ICAO Chapter 8 requirement and can completely eliminate testing in many locations since the wind speed at 150m (500ft) can readily exceed 10 knots. There is no evidence this has any marked impact on the overall noise levels, providing as required by ICAO, flight tests are conducted in two opposite directions. There is obviously some impact of using an 'average temperature and humidity' relative to that of at 10m: these will generally be small - in the order of 0.3dB or less. The main objection, from a manufacturer's perspective, was that these requirements dictate the use of a weather balloon and all the associated expense.

There were (and still are) a number of other differences which cause difficulties, these are discussed in Reference 9. The FAA rule also defines the flight path requirements to meet the 6° ±5° approach slope differently and sets limits of ±30ft (±9m) in the case of both flyover and approach. This latter requirement is similar to the ±10m (±33ft) requirement removed from Chapter 8 when the *no correction window* was withdrawn at CAEP1.

The Stage 2 noise limit, although the same as CAN7 and linked to the same *upper weight limit* of 176370lb (80,000Kg) as in Chapter 8, decrease at a rate of 3.01dB per halving of weight compared to 3dB in Chapter 8. This gives a *low break point* of 1764lb (800Kg) which is slightly different to that implied by Chapter 8 and as a result the noise limits are slightly different (by 0.1dB) at weights in the range of 800Kg (1764lb).

8. LIGHT HELICOPTER RULE

8.1 Background

The ICAO Working Group, together with the Technical Issues Sub-Group (TISG), placed considerable emphasis on developing a separate simplified scheme for *light helicopters* between CAEP1 (1986) and CAEP2 (1991). There was considerable debate in the early stages on how to define *light*; should it be related to weight, type of engine, number of seats, etc.? Initially there was no consensus between member nations: there was also no real agreement between the manufacturers. Subsequently, following a proposal by the U.K., the ICAO Working Group, agreed to base the *simplified scheme* on one for *piston engined helicopters*.

8.2 Units

A number of members supported the retention of the EPNdB used for Chapter 8. Others (including ICCAIA) preferred the SEL (Single Event Level) unit, which like EPNL takes account of both the subjective level and duration, since this would allow the analysis to be considerably simplified. There was a general feeling that any limits developed in SEL should be related to those of Chapter 8 and this lead to considerable discussion over the 'EPNL-SEL' difference. ICCAIA tabled a number of papers with data of the type shown in Figure 8 and ascertained that for a wide range of helicopters EPNdB (or EPNL) was 3.2 to 3.4dB larger than the SEL value. This agreed well with U.S. conducted tests (10) which indicated 3.3dB for the Robinson R22 piston engined helicopter. Although no specific relationship was agreed within the Working Group, it was generally accepted this was adequate to develop SEL limits.

8.3 Test Condition(s)

It was proposed that if any procedure was to be simple it should be limited to the one flight condition of *flyover*. This received various levels of support but many of the ICAO Working Group favored use of *approach* since it was argued this was the noisiest condition and more representative of the noise generated by helicopters particularly when operating into heliports. Others suggested both conditions should be embodied in any scheme, and some proposed it should also include take-off. Over the period from CAEP1 no clear policy emerged and there was essentially a stalemate between the *approach* and *flyover* groups. There was some shifts of opinion with time but these were not sufficient for a clear majority. Eventually, as CAEP2 approached, use of the *flyover condition* gained favor and it was adopted for the purpose of drafting a light helicopter rule designated Chapter 11. There was a similar debate on the number and location of the microphone(s) but it was finally agreed the tests should be limited to a single microphone under the flight path. The test speed was set at the same as used for Chapter 8 without much discussion.

8.4 Applicability

There was general agreement that some weight limitation needed to be applied to the *piston engine* designation if it was to be limited to *light* helicopters. The manufacturers did not initially have a common view but eventually felt that it would be logical to link it with the airworthiness rules which change at 2730Kg (6000lb). Some Working Group members felt this was too high and suggested 1000Kg (2200lb) or less. Since this could not be agreed a mass (weight) limit was not included in the Working Group recommendation to CAEP2.

One of the arguments presented in favor of the simplified scheme was that the noise from a piston engine helicopter was nominally unidirectional. Tests conducted in the United States, and reported to CAEP2, indicated that the noise field shapes were similar on 'light turbine powered helicopters'. This aspect was linked to upper mass (weight) limit and after consideration it was agreed that the scheme should cover all helicopters (ie. both piston and turbine powered) with a maximum weight of 2730Kg (6000lb) or less. This was, however, only reluctantly accepted by some members and one member disagreed with this policy and felt strongly the rule should be limited to *piston engined helicopters* only.

8.5 Scope

In the early stages of the development of the *light helicopter scheme* it was suggested, and supported by most national representatives, that the new Chapter 11 should be a *screening procedure*. The idea was that if an applicant failed to meet Chapter 11 they would then have the option to be certificated under Chapter 8 which consisted of 3 flight conditions, different limits, and trade off provisions. ICCAIA supported the general concept but felt that an applicant who met the Chapter 11 requirements should not be able to imply that the helicopter had met the requirements/ standards of Chapter 8. The final wording incorporated in Chapter 11 at CAEP2 reflected this aim.

8.7 Noise Limits

There was a general feeling within the Working Group, if the scheme was to be simpler than Chapter 8, and if there was an option to apply for certification under the existing Chapter 8, that Chapter 11 should be more stringent. After various discussions this increase in stringency was set at 2dB, thus logically since the EPNL-SEL is in order of 3.5dB or less, the limit in absolute terms would be expected to be 5.5dB below the absolute value of Chapter 8. This was essentially the Working Group proposal. The U.S., prior to CAEP1, conducted detailed tests and by examining the actual EPNL and SEL levels, concluded that to give a 2dB increase in stringency the Chapter 11 flyover limits in SEL should be set at 7dB below the flyover limit in EPNdB of Chapter 8. As a result at CAEP2 the -7dB was initially accepted. After making this decision it was pointed out that many of the *light helicopters* could not meet this requirement and thus they would be forced to seek certification under Chapter 8. After further discussion it was agreed that the limit should be relaxed to -6dB, relative to the Chapter 8 flyover value in EPNdB, which implies a 2.5dB increase in stringency. Even this was not agreed with full support and one member indicated strongly that the -7dB should be applied.

9. USA 'LIGHT HELICOPTER' RULE

During CAEP2 (Dec. 1991) the US delegation highlighted the importance of a simplified light helicopter rule to relieve the financial burden on the manufacturers of small helicopters and indicated they would issue a rule as soon as practical. It was anticipated, therefore, that the USA/FAA would issue a rule based on the newly agreed Chapter 11 (11) and the corresponding Appendix 7. The FAA issued NPRM 92-7 on June 24, 1991 (12): the proposed rule applied to all helicopters below 6000lbs (2730Kg), but contained several significant differences from ICAO Chapter 11/Appendix 7.

The two main differences are that the NPRM proposes use of a *atmospheric correction* and mandatory tests to be conducted at an *'adjusted airspeed'*, based on the Mach number of the advancing tip speed of the main rotor, while Chapter 11 does not include any such provisions. It is ICCAIA view, taking into account the added complexity in obtaining the data and the small magnitude of the corrections involved, that instead of a radically new correction procedure the same result can be obtained by use of a restricted temperature/humidity test window. The source noise correction procedure proposed (which is based on ICCAIA recommendations for use with Chapter 8) is technically supported, but it is questioned if this is justified in the case of a simplified scheme for light helicopters.

In addition a number of other minor differences are included in the NPRM, for example where as Chapter 11 specifies the temperature and humidity measurements to be taken at 10m or an aerodrome unit of within 2000ft of the test site, the NPRM dictates measurements at 1.2m.

These differences are now being discussed internationally and ICAO TISG is due to study some of the technical issues involved. It is hoped that this will lead to a US rule which is the same or very similar to ICAO Chapter 11 or some agreed form of an amended Chapter 11.

10. CHAPTER 8 ISSUES

10.1 Source Noise Correction

ICCAIA submitted a number of papers to both the ICAO Working Group and TISG over the years related to the *source noise correction* highlighting the technical uncertainties with the procedure and the high testing time and associated costs involved. If the Outside Air Temperature (OAT) at the helicopter flyover height is less than the reference temperature of ISA+10°, corrections will be negative. In other words if no correction is applied the quoted level would be higher than the corrected value. ICCAIA suggested it should be a manufacturers option to quote a slightly high noise level for the helicopter, particularly if this saved up to 50% of the total certification costs. ICCAIA further proposed that even a small error of 0.3dB should be allowed in which case the *source noise correction no correction window* (based on tests and theoretical studies) could be set at 28°C/82.5°F (approximately ISA+13°). Although TISG members appreciated the costs associated with the testing they did not support the concept.

In mid-1990 Westland suggested to the UK DOT/CAA, that adjustments for the *noise at source* could be effected by changing the airspeed (flight speed) and/or rotor speed to give the reference advancing blade Mach number. This proposal obtained support but not sufficient for TISG to make any specific proposals to the ICAO Working Group. A number of ICAO members expressed interest in the scheme but felt it was premature to consider any changes to Chapter 8.

The current accepted practice is to use a *PNLTM (PNdB)/Mach number curve* to determine the noise source correction. The presumption implied by using this is that the main rotor advancing blade tip Mach number is the controlling noise parameter: although this is not always the case it has been accepted, partly as a result of FAA Part 36 Appendix H requirements (8), for all helicopters certificated to date. Assuming this is the case then, as illustrated in Figure 9, measurements at the *reference Mach number* (at 0.85M on the figure) will give a more accurate result than correcting the tests results made at the 0.9V_H flight speed (equivalent to 0.862M on the figure) by subtracting the *'source noise correction* which is normally termed Delta 3. [The variation in data points around the 0.85M and 0.862M indicated on this figure is typical for a noise certification test.]

ICCAIA redefined its position and submitted to CAEP2 a proposal that Chapter 8 and Appendix 4 should be *"amended to allow overflight tests, in the case when the advancing blade tip Mach number is the noise correlating parameter, to be conducted at a flight speed which maintains the advancing blade tip Mach number at the value obtained under reference conditions"*.(13) It was not considered justified by CAEP2 to change Chapter 8 but a majority of members considered this was a good candidate as an equivalent procedure and for subsequent inclusion in the companion *ICAO Environmental Technical Manual*. CAEP2 also expressed the view that *"individual certificating authorities could give the method consideration if required in the meantime"* for use in compliance with the noise source correction requirements. Industry felt this was a satisfactory position but still considers that Chapter 8 should be amended to indicate this method can be used. In this context it is of interest to note that the FAA incorporate this procedure in their proposed rule for *light helicopters* recently issued in NPRM 92-7 (12). Hopefully this will receive wider acceptance for use with Chapter 8/FAA Part 36 compliance.

10.2 Simplification

The manufacturers have been working since CAEP1 to develop a simplification framework for Chapter 8/Appendix 4 which is considered to be too costly and complex. Added to this is the fact that the magnitude of the *complete delta 1 and delta 2 correction* are typically within 0.25/0.3dB or less as indicated in Table 1 for one certification test. The two exceptions to this are in the case of the flyover where the *source noise correction (delta 3)* using the current procedure can lead to corrections of 1EPNdB or more. This can be easily handled by the procedure discussed previously. The corrections in the case of take-off can also be relatively large, in the order of 2EPNdB, if the standard procedure illustrated in Figure 5a is applied, since the altitude over the microphone will be high or low compared to reference value. This is reduced to a very small value (0.3dB or less) if the *break point B* is moved as shown in Figure 5b.

It is ICCAIA's view that since the correction can be small than an applicant should have the option of conducting tests with a *no correction window* or what is known within ICAO as a zero *adjustment test window*. The proposals made by ICCAIA to ICAO CAEP2 are detailed in references 14 and 15. It is proposed that the *no correction window*, deleted at CAEP1, is reintroduced, together with a restricted *temperature/humidity zero absorption window*, similar to that approved for *light propeller driven aeroplanes* and embodied in Chapter 10/Appendix 6. Such a limit is indicated in Figure 10 which shows the magnitude of the *delta 1 corrections* for a representative helicopter: it will be noted these corrections are small. Also shown is the 12dB/100m atmospheric absorption in the 8kHz 1/3 octave band 8kHz band 'cut off' and typical test condition ranges measured in the UK and USA. Where the distance exceeds the ±10m (±33ft) defined by the *no correction window* then ICCAIA proposes a simplified correction based on height, rather than PNLTM point or the closest point of approach (CPA). [This would replace the current delta 1 and -7.5log term of delta 2.] ICCAIA also suggest that by making it mandatory to conduct take-off and approach tests into wind (which is the normal practice for safety reasons), the requirements for ground speed could be eliminated since this always gives a 'negative correction' which is typically 0.3dB or less. If all these proposals were adopted - and there is little point in any individual aspect being considered in isolation - then *as measured data* could be used to give the certificated level. This would enable tests to be conducted with the minimum of equipment and since, in the case of height/off track it would only be necessary to ascertain if the helicopter was within the prescribed window, no costly analysis and data correction would be involved.

ICCAIA proposals have not, to date, received much support within ICAO even so, largely as a result of the high cost involved with certification it was agreed at CAEP2 that there was a need for simplification of Chapter 8 and this was included in the terms of reference of the new Working Group. One of the major problems in getting acceptance of any change in the requirements is the fundamental belief that the current procedures will always give the same result within 0.1EPNdB. ICCAIA have suggested if the results are within 0.25 or 0.3EPNdB, compared to that obtained by true analysis, this should be acceptable.

10.3 Rate of Descent

A proposal was introduced into TISG by France in April 1988 to place a limit of ±0.756m/s (±150ft/m) on the Rate of Descent (RoD) variations which occur during *approach*. The argument was that since noise is a function of the *aerodynamic slope (descent rate/angle)*, then noise variations must occur and limitations should be applied. This is fundamentally true but ICCAIA suggested such a requirement was inappropriate in the context of noise certification based on a constant 6° slope and Vy speed and if the RoD was based on a *short duration* variations then most, if not all, helicopters would fail to meet the proposed limit. Similarly once the wind speed, at test height exceeded 14 knots, the RoD (assuming all other parameters are constant) would exceed the value suggested. Data presented showed that RoD variations were significantly greater than the proposed limit, particularly if a short term integration times were used, and that they had no influence on noise levels measured in terms of PNLTM or EPNL values. This and other inputs subsequently lead to the RoD proposal being withdrawn.

10.4 Approach Angle

Prior to CAEP1 the approach test involved conducting flights on 6° glideslope and ensuring that over the '10dB period' the helicopter profile was within ±10m (±33ft) and the corresponding ±10° zenith. When the ±10m *no correction window* was deleted, the requirement was replaced by one which required conducting the flight test within 6°±0.5°: the ±10° zenith was retained together with the 6° reference.

When applicants commenced certification testing they found difficulties in both the interpretation and application of the ICAO and FAA requirements. The intent of the procedure developed at CAN6 was for the helicopter to be flown with a *6°±0.5° airspace wedge*. A number of authorities appeared to interpret the regulation to require the *mean flight angle* over the 10dB points to be within 6°±0.5°. This can be understood by reference to Figure 11, which shows an approach within the *wedge* with a mean angle (based on the radar altimeter readings) of 6.7°. Also indicated are the corresponding *mean results* based on various camera positions which indicate a 5.9° or 6° value. Some authorities stated that such a flight would 'fail' to meet the requirements. It was stated that, since the noise generated varies with approach angle, then there would be a marked difference in noise with different paths within the *wedge* and that the applicant (manufacturer) could use this to generate lower noise levels for certification. This is not the case since the pilot is attempting to fly down a beam (usually a beam of light from a PLASI system) set at 6°. The hypothetical case of being able to adjust the flight path within the wedge is not possible - in fact many pilots experience difficulty of simply flying within the *6°±0.5° wedge*. During this evaluation it was discovered that the 'French version' of ICAO Annex 16 stated that tests should meet a mean angle of 6°±0.5° while the 'English version' implied use of a 6°±0.5° *wedge*.

It was found that use of the requirement for a mean angle of 6°±0.5° resulted in a dramatic increase in the rejection of 'good flights' by up to 8 to 1 in the case of one certification exercise. It was known that such differences have negligible impact on the noise, however, this was difficult to document.

ICAO Working Group II and TISG examined this in depth, with inputs from the UK CAA, including an evaluation using a flight simulator. It was finally agreed that it would not be possible for an applicant to exploit the requirement if, in fact, it was defined as a *airspace wedge of 6°±0.5°*. As a result changes to the appropriate section of Chapter 8, and modification to the French version, were agreed within the Working Group and ratified at CAEP2. The FAA rule, however, continues to imply that a mean angle over the 10dB points of 6°±0.5° is required.

10.4 3°,6°,9° Guidelines

ICCAIA members, although not very enthusiastic with the concept, agreed at CAEP1 to collect such data during subsequent certification exercises. Unfortunately manufacturers have been forced to drop such tests as a result of pressure to reduce cost in an hardening economic climate. As a result, except for some measurements by two manufacturers which have not been analyzed, there has been no direct studies of use of the 3°,6°,9° procedures. This is not to imply that an 'alternative approach' is not required since, if anything, the opposite is true. Also allowing flexibility in the approach procedure could stimulate real decreases in the noise generation during approach and at the same time set the scene for a future reduction of the noise limits.

11. NOISE CERTIFICATION EXPERIENCE

11.1 Certification Applications/Tests

Table 2 lists the status of certification application/ tests on 1 January 1992 according to information supplied by ICCAIA members. This does not include many of the applications made by manufacturers of smaller helicopters, or applications made within the USA by the *'modifiers'* to the FAA. This table lists 33 helicopters of which 23 are derivative designs, 3 existing designs, and only 6 are new designs. To date, again according to available information, certification has been approved for the 10 helicopter types which includes the A109K2 certificated to the requirements in Switzerland (CAN6 limits).

11.2 Number of Flights Required

ICAO established a confidence limit of ±1.5EPNdB and determined that the minimum sample size (number of flights) to meet this would be six. The FAA in the US rule adopted a similar requirement for 6 flights for each condition. This implies a total of 18 flights. The *source noise correction* dictates tests at other speeds and, depending on the number of different speeds deemed necessary to provide a satisfactory PNLTM/Mach Number dependency, this implies, assuming 6 per flight speed, 12 or 18 flights depending if 2 or 3 additional speeds are evaluated. This effectively doubles the basic requirements and gives a total of 30 to 36 flights. Data from a number of the certification programs have indicated that in practice they are considerably higher. In one case the total was 175 and even if the cases where the total number of flights were low, additional flights were often required for *training*. The *approach* has a high rejection rate, mainly as a result of the FAA requirements for a mean angle of 6°±0.5° over the 10dB points. The 'failure rates' vary from 2:1 to 5:1. Take-off is similar and this would appear to be more associated with learning the certification technique. In the case of flyover again there are some large differences but when comparing the number of flights care must be taken to ascertain the *number of additional speeds* flown. Some applicants have obtained approval to use *3 speeds* while others have used *4 speeds*. In some cases the number of flights in a *speed set* have to be decreased to 4 and other applicants have obtained approval by simply conducting additional individual tests over a range of speeds rather than 4 or 6 flights at specific speeds to provide data for determining the source noise correction. In the case of the very high number of tests by one manufacturer, indicated in Table 3, these were a result of attempting to meet the FAR Part 36 10 knot wind speed limit at the flyover height.

Typically rejection rate is in the range of 2:1 to 3:1 which a extreme case of 5:1 and this obviously accounts for much of the high cost of noise certification.

11.3 <u>Certification Costs</u>

Certification cost data submitted to CAEP2 by ICCAIA is reproduced in **Table 4** and, as indicated, ranges from $120,000 to $600,000 (US Dollars, 1989/90 rates) giving an average of $275,000. This is a little less than estimated at the time of CAEP1 mainly due to the fact it <u>excludes</u> non-recurring/investment costs for facilities, test equipment etc. Precise information on the magnitude of these costs are not available but based on information from AIA members this would appear to be in excess of $500,000 for each of the major US manufacturers.

The costs for the tests conducted in Europe, by Aerospatiale and Agusta, are slightly lower than the corresponding values for tests within the USA. Firstly it should be noted that the *accounting process and/or the allocation of charges for use of airfield facilities, helicopters flying time, etc.* differs significantly between companies and within different countries. The costs are also somewhat dependent on the size of the helicopter, since *flight hour changes* are usually higher on larger, and often more sophisticated helicopters. Also in the case of Aerospatiale the altitude weather measuring equipment, including the technical support, was provided by the French DGAC and the Agusta information is based on *partial budgetary costs* only.

The tests by Aerospatiale and Sikorsky cover both Chapter 8 and FAR Part 36 Appendix H, while those for the Agusta 109 are related to Chapter 8 only. The other costs listed are for compliance to the FAA rule only which, as highlighted previously, is more demanding.

The break down of the certification costs, on average, are aircraft and site instrumentation 25%, testing 38%, data processing 21%, report 8% plus an additional 8% for planning and coordination.

Information in Reference 16 indicates that meeting the windspeed requirements, during tests in France to ICAO and FAA standards *"easily doubled flight costs and measurement costs for the on-ground team"*. It is also stated that the more rigorous interpretation of the 6°±0.5° slope for the FAA rule resulted in a 2 to 1 rejection rate for test flights as compared to meeting Chapter 8 requirements. It is, however, not possible to precisely ascertain what would be the average cost for a Chapter 8 type certification relative to that for compliance with FAA part 36. Even so it is clear that the magnitude of the costs are unacceptably high.

11.4 Certification Noise Level

The noise levels made available by ICCAIA members, as of 1 Jan. 1992, are summarized in Table 5 and illustrated in Figure 12 relative to the ICAO CAN7 (FAA) Noise Limits. Some additional data has recently become available and this is included on Figure 12. The CAN6 noise limits are also indicated for reference - data for the Agusta A109K2 is included but since this is certificated to the Switzerland rule (CAEP1 procedures) it has to meet the CAN6 limits. Also indicated on the figures for reference is some *manufacturers data* derived from tests conducted to certification standards.

It will be seen from the figures that there is a tendency for the margins, relative to the certification limits, to be larger at the low weights than associated with medium weight helicopters. In fact the slope appear higher than 3dB/doubling of mass and in the mid-weight range is more akin to 6dB/doubling (this slope is illustrated on Figure 12 for reference). The only real exception to this trend is the AS332L1 which generates relatively lower levels. However, care must be taken when evaluating this data since the number of *basic helicopter types* is relatively limited. Also with the exception of the MD500N, all are derivative designs.

The values indicated on Figure 12 are based on the results on the primary national certification authority. As shown in Table 5, which lists the detailed noise data for all the certification tests, the difference between ICAO Chapter 8 and FAR Part 36 is 0.1dB or zero (0dB). It will also be noted that the *noise limit* associated with FAR Part 36, which is based on 3.01dB/doubling of mass as compared to the Chapter 8 3dB/doubling, is also up to 0.1dB different in the case of the *light helicopter*.

12. THE WAY FORWARD

12.1 Procedures

It is often mentioned that 'noise certification' is simply a method of showing compliance with specific noise limits. This was somewhat true when CAN6 procedures where developed since, providing tests were conducted with a defined set of limits, no correction were required. Thus effectively *as measured data* could be used to ascertain to see if it was lower than the limit and in this case the helicopter would be deemed to pass. Over years considerable changes have taken place both with regards to fixed wing aircraft and helicopter noise certification. Now the industry is faced with a set of requirements, complex in nature and costly to perform, **with a requirement not only to show the noise level(s) are below a particular limit but to calculate the absolute value within 0.1dB.** This is often difficult to understand when the best that data can be measured to is 0.25EPNdB. In addition most acoustic engineers are surprised if test to test variations are less than 1dB! In this respect it is also worth remembering the HNMRP study indicated variations of over 3EPNdB for each of the 3 flight conditions. It is often argued that *accurate* data is required because it is used for other purposes; this may be true but the cost of developing such data in that case should not be borne by the manufacturers and hence users. Simplification to reduce the cost impact is considered essential by the industry, but progress toward this end often gets bogged down since it is stated that any change/simplification must give the same result to within 0.1dB. By definition some loss in accuracy, even if its only 0.25 to 0.3dB, must occur if the procedures are to be simplified. It should also be remembered that except for flyover, the test conditions bare little resemblance to those used in practice. The 'take-off' is unrealistic and helicopters do not fly a constant approach glideslope: the only exception is the case of IFR/ILS procedure and even in this case a constant Vy speed is unlikely over a significant position of the approach procedure and 6° it only a proposal as a future IFR standards. It is also difficult to imagine a use, taking these aspects into account, where a accuracy of 0.1EPNdB would be required.

Internationally, although harmonization is agreed by all to be a desirable aim and ICAO provides a forum debating and agreeing noise certification requirements, the industry is still today faced with two basic sets of standards namely ICAO Chapter 8 and FAR Part 36 Appendix H. With the advent of JAA, which has not yet commenced a formal effort to issue common JAR Part 36 standards but is expected to do so in the near future, minor differences in the interpretation and application of ICAO Chapter 8 in Europe will be resolved or reduced. There does not, however, appear to be any move to resolve the outstanding differences between Chapter 8 and FAR Part 36 Appendix H and the issue has been further complicated by the recent FAA NPRM which indicates that FAR Part 36 Appendix J for light helicopters will likely be different from ICAO Chapter 11. Hopefully once the differences related to the light helicopter rule are satisfactorily resolved, the FAA and JAA (within or outside ICAO) will get together to tackle harmonization of Chapter 8/FAR Part 36 Appendix H. Currently there is a situation where although both procedures give results which are within 0.1EPNdB of another, very different analysis procedures have to be followed. In addition the requirements, particularly the *10 knot altitude wind speed requirements* in FAR Part 36, elevates the costs considerably.

In this context it must not be overlooked that even if harmonization between the US FAR Part 36 and ICAO rules could be achieved, there is still a need for simplification. It is the author's view that the best approach would be to consider a dramatic re-appraisal of all the requirements and place a major effort on 'simplification' along the lines proposed at CAEP2 (18). If this could be agreed as a **option or equivalent procedure for all rules**, then maybe the difficulties associated with changes of the rules within individual nations would not need to be addressed.

12.2 Stringency

Whenever simplification is raised it is immediately linked with a future increase in stringency (reduction in noise limits). Increasing stringency is related to, from a public perspective, lower helicopter noise levels which can on existing helicopters be achieved only by re-design and/or a decrease in performance which leads to increased operating costs. Clearly a balance has to be found since, irrespective of noise certification, it is necessary to design/operate helicopters such that the noise generated is compatible with their use, which in some cases means even lower levels than dictated by certification. There is no new technology anticipated in the foreseeable future which is going to lead to the possibility of dramatic noise reductions, thus the designers/manufacturers are faced with using available technology and optimize it to minimize the noise generation. This is discussed in some depth in Reference 19, together with uncertainties associated with prediction etc., on design margins. Added to this is the fact that success of helicopter designs, with one or two exceptions, depends on meeting both civil and military design/performance requirements, since only on this basis can the high design and development investment be justified. Thus *true civil only helicopters*, except in the very small/light end of the market, are not economically viable. As a result there is <u>no</u> parallel with the fixed wing passenger aircraft market and the introduction of one or two purely civil helicopters in the light-medium weight range in the early 1980s is unlikely to be repeated. Added to this is the fact that most civil helicopter types, which are usually based on a military *parent* or make use of common components, are developed over many years so that it is the *derivatives* which dominate the helicopter field. This can be appreciated by studying current applications of noise certificates (Table 2) which include 26 derivative designs or existing designs and only 6 new designs of which most are either based on common military and civil designs, or make use *of earlier civil/military dynamic components*. This background is very important when considering the noise limits to be applied in the near and long term since, to some extent **the levels generated by today's helicopters are indicative of those likely on derived versions in the future.** This is not to imply that noise reductions are not possible since, in the case of new helicopters, some encouraging low noise results have been obtained on some designs: the MD500 and EH101 (20) are such examples. *In addition optimization of rotor systems for noise*, either by blade design changes or configuration changes can lead to low levels: the results of noise reduction program associated with the Lynx military helicopter, for example, has indicated that reductions are possible even on high performance helicopters (21).

Lowson (20) has suggested that there has been a significant reduction in helicopter noise over the years. This magnitude of this reduction must, however, be questioned since the early data base was heavily dominated by military designs, which tended to be large in size and inherently generate high levels, while the *new designs* are focussed on the civil market and mostly in the light/medium weight categories. Some reductions have been possible by the use of low rotor tip speeds but there is a limit and as illustrated by Lowson's data the reduction may have *flattened out*.

The current position suggests, to the author, that if changes in requirements are to be made then *new designs <u>and</u> derived* versions would be treated differently since there is *more flexiblity* on new designs, then in the case of derived versions. It would appear that if any changes to noise limits/stringency are to be made then initially they should be limited to **new civil designs** only with, say, the limit set at 'CAN7 -2EPNdB' in 1996 and in the longer term (1999), *if technology development justifies it*, CAN7-3EPNdB (ie CAN6). Based on the current data

(Figure 12), there is little possibility of decreasing the limit for 'derived versions' of the current fleet, but assuming the existing data/trends are substantiated by future certification results, than there may be a case for looking at a 1 or 2dB per condition reduction in the long term, say, 2000+.

13. CONCLUDING REMARKS

Noise certification has undoubtedly played a major part in focussing attention on the noise generated by helicopters and the CAN7 limits have effectively *capped helicopter noise levels.* Thus as a result of a number of the very noisy designs, based on military helicopters, have tended to have been phased out and today's fleet are moving towards quieter designs. Newer designs are being produced with lower noise but not in sufficient numbers to justify an immediate reduction in the noise limits. Thus a 3dB/condition (9dB total) reduction would appear a desirable aim for new designs before the end of the century. In the case of derived versions, the economic backbone of the industry, little reduction can be envisaged which would not have a dramatic impact in terms of the number of helicopter types and operating costs. Thus the certification scheme needs to opened up to allow *noise abatement* and or other similar procedures to be exploited: this, if adopted, could lead to lower levels experienced by the public and an avenue to reduce future limits. The main problem with noise certification, however, relates to high cost and complexity which can only be resolved by harmonization between the various standards and an overall simplification. Adoption of the light helicopter rule will be a significant help at the lower end of the market: this philosophy of simplification, however, needs to be extended across the board.

14. ACKNOWLEDGEMENT

The author offers his appreciation to Charlie Cox (Bell Helicopters) and Tony Pike (Westland) for their help and advice in preparation of this paper. **The views expressed, however, are those of the author and should in no way be taken to indicate the policy of E.H. Industries, Westland Helicopters or ICCAIA.**

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TABLE 1
MEAN CORRECTIONS

	Δ1	Δ2	Δ3	ΔTOTAL
APPROACH	<-.1	<-.1		-.1
TAKE-OFF	.5	-.2		.3
FLYOVER	.2	0	.8	1.0

	Δ1	Δ2	Δ3	ΔTOTAL
APPROACH	<.1	<-.1		.1
TAKE-OFF	-.3	.3		0
FLYOVER	<.2	0	<.3	.4

Δ1; Δ2: ICAO CHAPTER 8
Δ3: SOURCE NOISE CORRECTION

TABLE 2
STATUS OF HELICOPTER NOISE CERTIFICATION

HELICOPTER MODEL	CERTIFICATION AUTHORITY					FULL NOISE TEST		REMARKS
	FAA STAGE 1	FAA STAGE 2	CAA	DGAC	OTHER	DATE COMPLETED	DATE PLANNED	
AEROSPATIALE								
AS 350 B1		C	C	C		1986		DGAC approved Feb 87
AS 350 B2		C	C	C				DGAC approved Jun 90 (by analysis)
AS 355 F1R	N							Stage 1 approved Feb 91
AS 355 F2R		A	A	A		June 91		
AS 332 L2		A	A	A		July 90		
AS 365 N2		C	C	C		Apr 90		DGAC approved Oct 90
AS 355 N		A	A	A			1991	
AGUSTA								
109C	N		A		A(FRG)	Oct 90		Stage 1 approved Aug 89
109K					A(SWIT)		1991	
BELL								
205B	N							Stage 1 approved Aug 89
412SP		C				May 90		FAA approved Aug 91
412HP	N	C				May 90		FAA approved Aug 91
230		A			A(CAN)		1992	
206L-4		A					1992	
MBB								
BO108							1992/93	Application pending
ENSTROM								
480/TH-28		A					1992	
MDHC								
369L	A							Application withdrawn
500ER		A		A		Nov 90		
500N		C				Mar 91		FAA approved Sept 91
MD900		A					1993	
ROBINSON								
R22 MARINER				A		Aug 89		Reported by WGII
R44		A					1992	
SIKORSKY								
S-76A		C	C			July 89		FAA approved Sep 89;CAA approved Dec 89
S-76A (STC)		C						FAA approved Apr 90 (by analysis)
S-76C		C	C			Aug 90		FAA approved Nov 90;CAA approved Jan 91
S-76C (STC)		C						FAA approved Mar 91 (by analysis)
S-76C (New tail rotor)		A	A				1991	
S-76D		A					1992/93	
S-70	N							Stage 1 approved Oct 1988
S-2000		A					1994/95	
SCHWEIZER								
330		A					1992	
E.H. INDUSTRIES								
EH101-300		A	A				1992	
EH101-500		A	A				1992	

Note: Models whose application for type certification or change in type design was received by cognizant authority on or after effectivity date(s) of each country's noise regulation.

A: Application made
C: Noise Certification approved
N: 'No Acoustical Change' determination: U.S. Rule
(by simple comparative test or analytical procedure)

TABLE 3
NUMBER OF FLIGHT CONDITIONS

	F/O	T/O	APP.	TOTAL
REQUIREMENT	18-24	6	6	30-36
AS332	37	23	19	79
AS365	25	14	15	54
AS355	31	14	10	55
B412	110	22	43	175
B230	63	24	21	105
S76A	44[1]	13	33	99
S76C	46[2]	9	12	57

TRAINING TIME: +60%[1]; +50%[2]

TABLE 4

COST BREAKDOWN OF HELICOPTER NOISE CERTIFICATION TEST PROGRAMS

US$: 1989/1990

	AEROSPATIALE			AGUSTA	BELL	MDHC		SIKORSKY	
	AS355F2R	AS365N2	AS332L2	A109C	412SP	500N	500ER	S76A	S76C
TEST PREP.	7,000	7,000	7,000	32,072	54,458	17,340	2,400	38,600	24,800
SITE INSTR.	43,200	43,200	43,200	INCL. BELOW	58,136	16,200	4,200	78,200	39,600
AIRCRAFT INSTR.	5,000	5,000	5,000	5,565	176,162	13,800	1,800	41,100	20,700
TEST	15,670	72,800	106,400	132,363	122,217	148,810	85,310	244,300	108,100
DATA PROC.	53,720	59,520	59,520		37,600	24,000	19,200	160,900	60,400
REPORTS	24,800	24,800	24,800		30,000	19,200	8,400	36,800	17,500
TOTAL	146,390	209,320	242,920	170,000 (Partial)	478,573	239,350	121,310	599,900	271,100

TABLE 5
HELICOPTER NOISE LEVEL DATA (1 JAN. 1992)

HELICOPTER Make & Model	MGW (kg.)	FLIGHT CONDITION and NOISE LEVEL (EPNdB)									CERTIFICATION AUTHORITY
		OVERFLIGHT			TAKE - OFF			APPROACH			
		** CH 8	Data	Margin	** CH 8	Data	Margin	** CH 8	Data	Margin	
AEROSPATIALE											
AS 350 B_1	2,200	92.4	87.3	5.1	93.4	89.7	3.7	94.4	91.3	3.1	France
AS 350 B_2	2,250	92.5	87.6	4.9	93.5	89.8	3.7	94.5	91.4	3.1	France
AS 365 N_2	4,250	95.3	91.2	4.1	96.3	93.2	3.1	97.3	96.2	1.1	France
BELL											
412 SP	5,397	96.3	93.4	2.9	97.3	93.2	4.1	98.3	95.6	2.7	United States
412 HP	5,397	96.3	93.4	2.9	97.3	92.8	4.5	98.3	95.6	2.7	United States
McDONNEL DOUGLAS											
500 ER	1,360	90.3	* 86.7	3.6	91.3	* 87.6	3.7	92.3	* 90.3	2.0	United States
500 N	1,520	90.8	80.2	10.6	91.8	85.4	6.4	92.8	87.9	4.9	United States
SIKORSKY											
S-76A	4,898	95.9	92.8	3.1	96.9	92.5	4.4	97.9	95.6	2.3	United States
S-76A	4,898	95.9	92.8	3.1	96.9	92.5	4.4	97.9	95.5	2.4	United Kingdom
S-76A (STC)	4,898	95.9	92.6	3.3	96.9	92.3	4.6	97.9	96.1	1.8	United States
S-76C	5,306	96.2	93.2	3.0	97.2	96.0	1.2	98.2	97.7	0.5	United States
S-76C	5,306	96.3	93.2	3.1	97.3	96.0	1.3	98.3	97.7	0.6	United Kingdom
S-76C (STC)	5,306	96.2	92.8	3.4	97.2	96.1	1.1	98.2	97.7	0.5	United States

* Preliminary data, currently not approved by certification authority

** FAR 36 for United States Certification

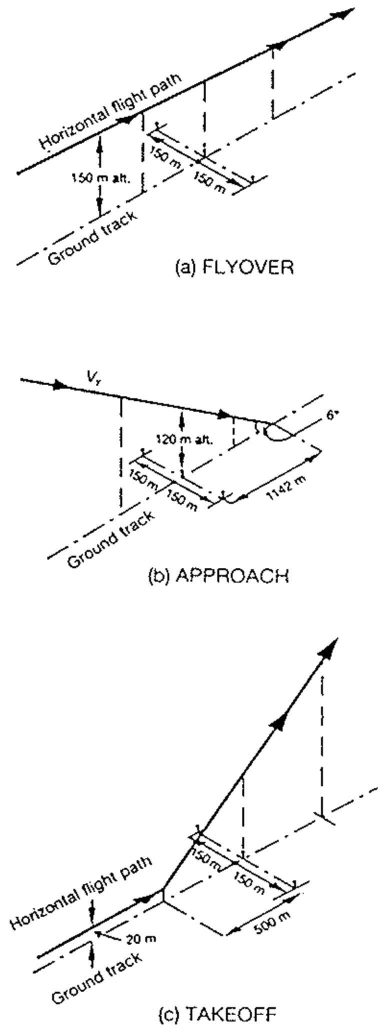

FIGURE 1: NOISE CERTIFICATION TEST CONDITIONS

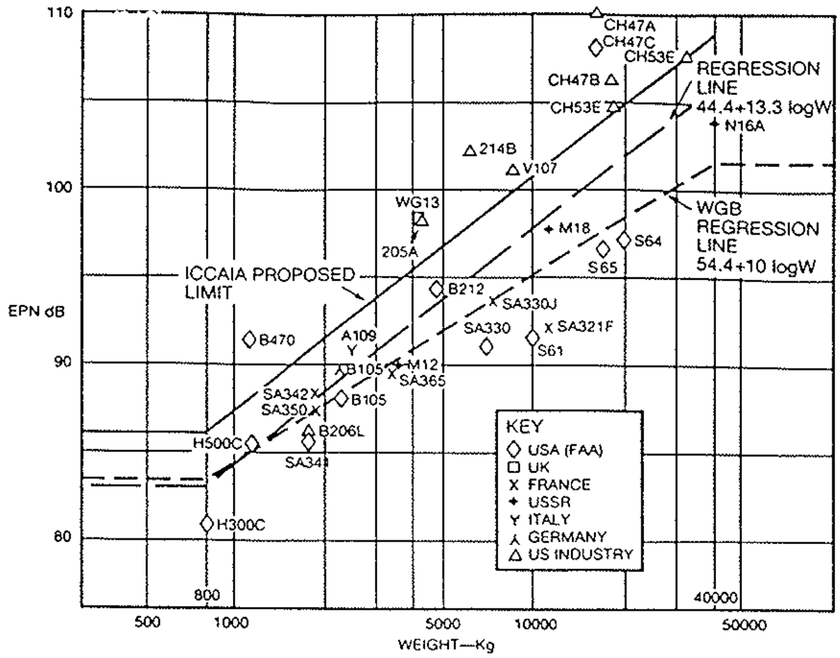

FIGURE 3: CAN6 FLYOVER NOISE DATA

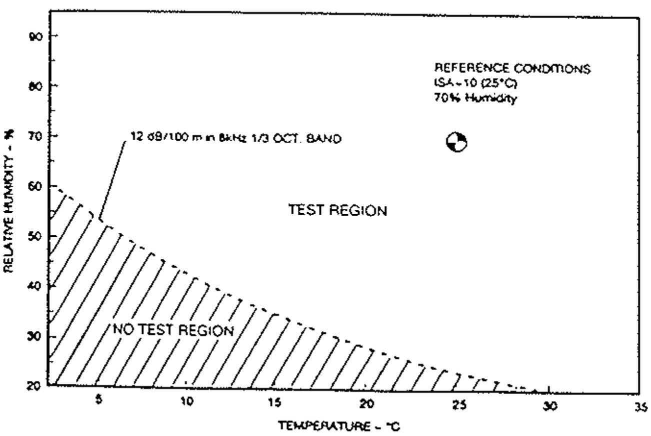

FIGURE 2: TEMPERATURE/HUMIDITY TEST WINDOW

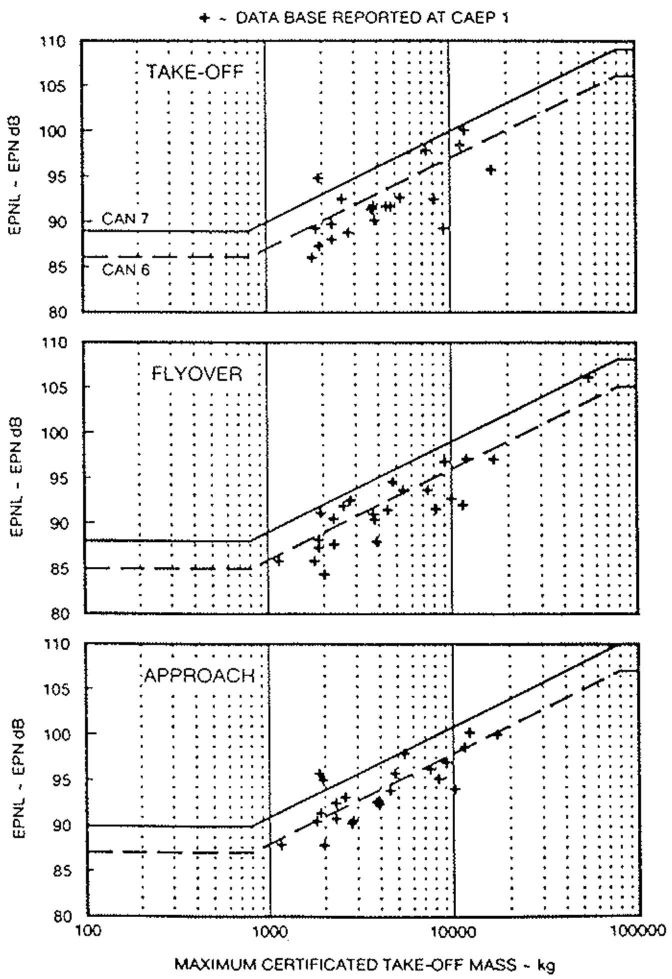

FIGURE 4: NOISE CERTIFICATION LIMITS

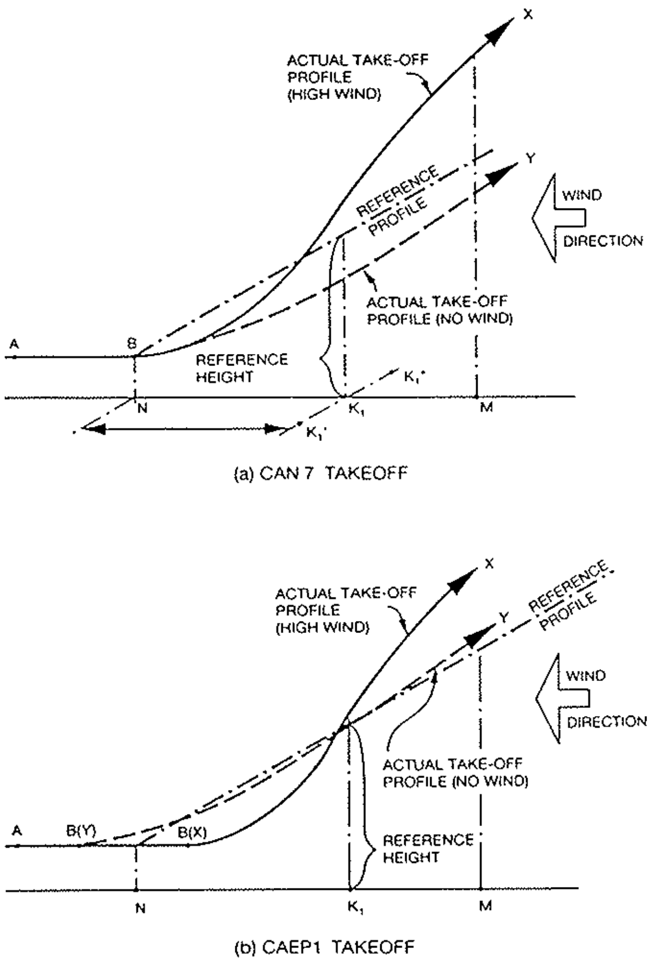

FIGURE 5: TAKE-OFF PROFILE

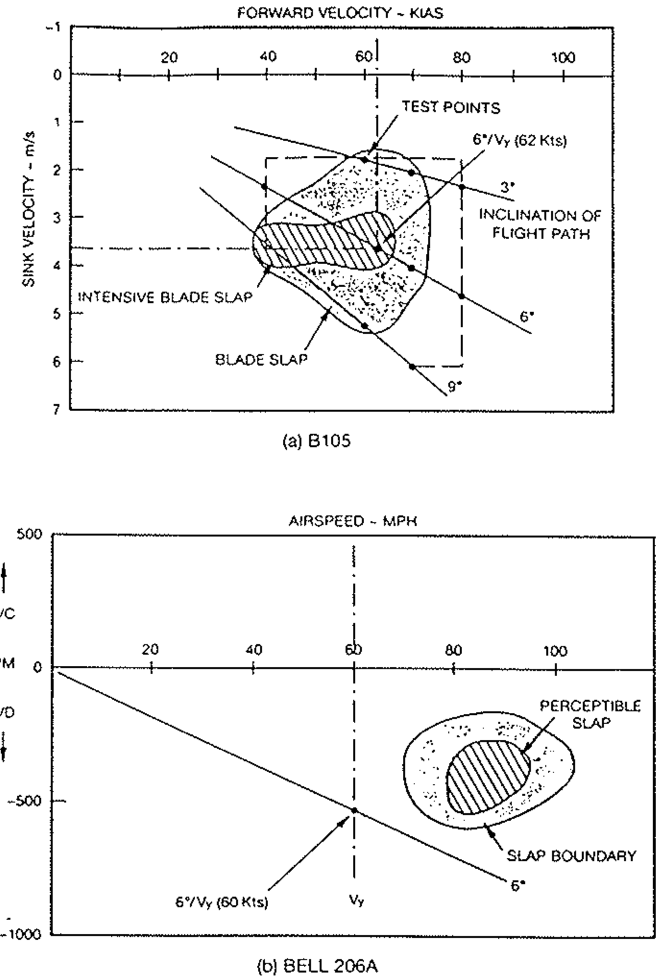

FIGURE 6: IMPULSIVE NOISE BOUNDARIES

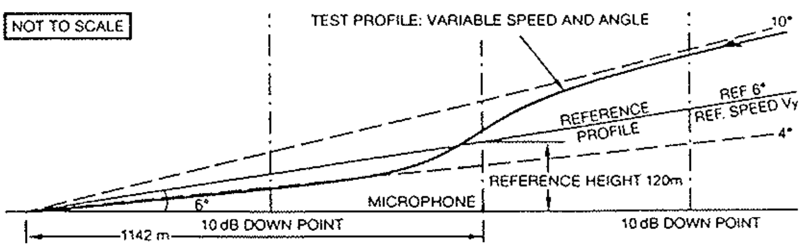

FIGURE 7: ALTERNATIVE APPROACH PROCEDURE

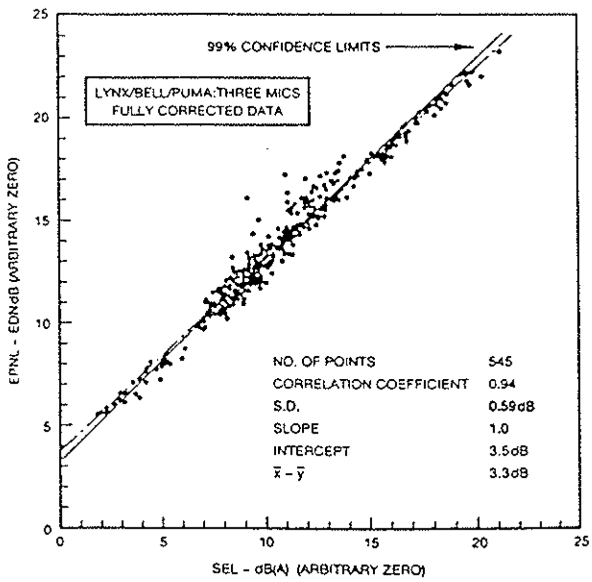

FIGURE 8: EPNL/SEL RELATIONSHIP

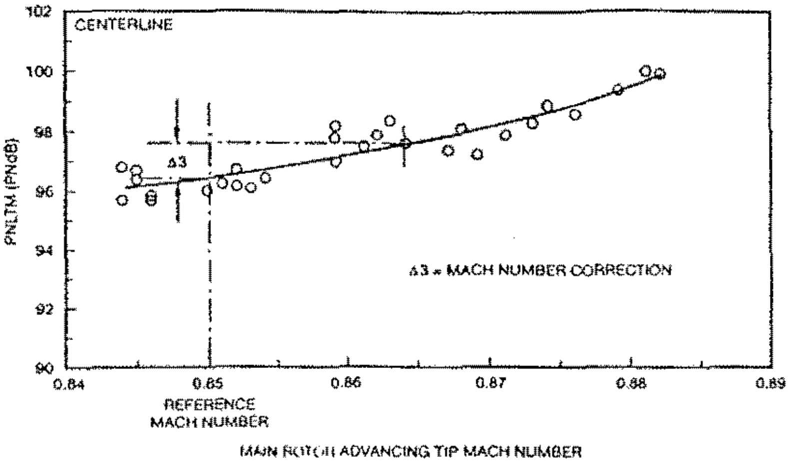

FIGURE 9: SOURCE NOISE CORRECTION

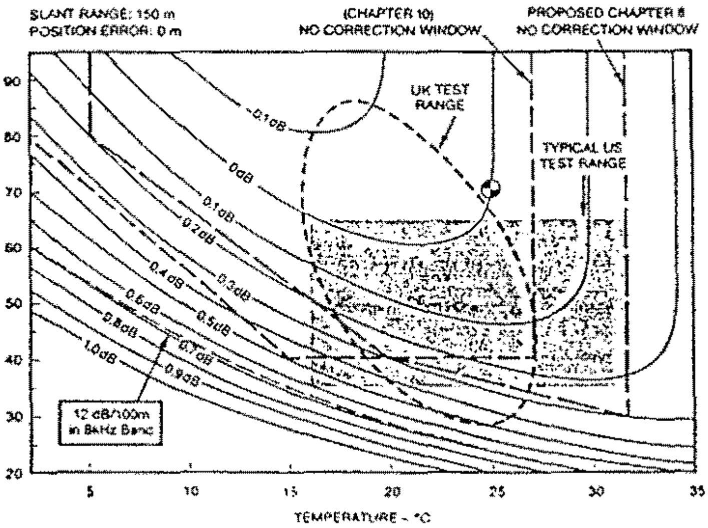

FIGURE 10: DELTA 1 CORRECTIONS/TEST CONDITIONS

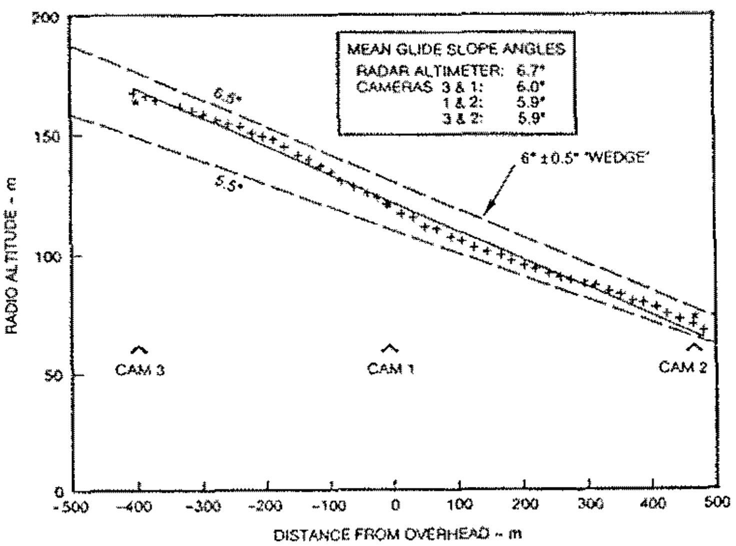

FIGURE 11: APPROACH ANGLE

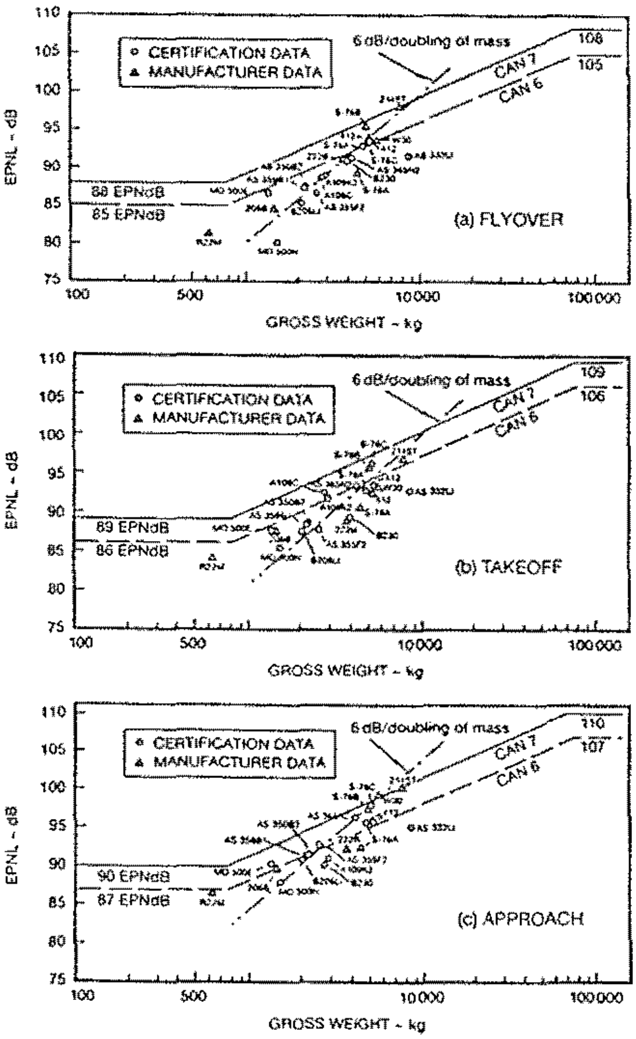

FIGURE 12: NOISE LEVELS