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HELICOPTER NOISE CERTIFICATION EXPERIENCE AND COMPLIANCE COST REDUCTIONS

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Abstract

This paper reviews the development of civil helicopter noise certification standards, summarizes recent compliance experiences and related program costs, and identifies improvements in the noise certification process which can reduce its complexity and cost. Certificated noise levels and compliance margins for twenty-five helicopter models are presented. It is shown that, on average, compliance margins are less for the larger helicopters than for the smaller ones. The costs to noise-certificate nine of these helicopters are then summarized and are shown to be high. In that summary, three primary cost drivers are identified: the extensive aircraft and site instrumentation used, the flight time necessary to meet all noise test requirements, and the amount of data processing. Ways are described to lessen the complexity of helicopter noise standards and to reduce the costs of compliance. Ongoing studies within ICAO and by industry are also discussed in which proposed improvements in the standards are identified. These improvements include a simplified noise certification scheme, less complex procedures in conducting noise testing and in making data adjustments, and less rigid applicability requirements when dealing with helicopter derived versions, upgrades, and modifications which may involve an acoustic change.

Introduction

To address environmental concerns related to aircraft noise, civil aviation authorities worldwide have developed noise standards. Such standards are designed to limit the maximum noise emissions of aircraft while encouraging the development of quieter designs. External noise standards currently exist for four categories of civil aircraft: supersonic airplanes, subsonic jet transports, propeller-driven airplanes, and helicopters. Noise certification requirements for ultralight aircraft have been drafted, and the requirements for future powered-lift aircraft (including tiltrotor and tiltwing) are under consideration.

The development of noise standards for civil helicopters was initiated by the International Civil Aviation Organization (ICAO), beginning in the mid 1970's. In this development, maximum noise limits were chosen, the requirements for noise testing and data processing were defined, and the applicability of the standards to different categories of helicopters was established.

In this paper, this development is reviewed, including a brief history of the decisions made by ICAO, the implementation of helicopter noise standards by different countries, and a summary of the noise certification requirements. The compliance experience to date and the costs of meeting current requirements are then discussed. Finally, means by which the costs of compliance can be reduced are identified.

Noise Standards Development

Noise standards for helicopters were developed in a relatively short period of time, without actual test experience or full appreciation for the economical risks to the industry. As a result, the original noise limits had to be raised during the development, the applicability of the standards to different helicopter categories was changed, considerable complexity was added to the reference test procedures and requirements, and implementation of the standards has not been the same in all countries.

History

At the sixth meeting of ICAO's Committee on Aircraft Noise (CAN/6), noise certification standards were introduced for helicopters (Ref. 1). These standards became initially applicable on November 26, 1981 and are referred to as ICAO Annex 16, Chapter 8. Maximum noise limits were established based on measurements taken with methods similar to certification, but not conducted specifically for certification purposes, and also on calculations from general flight tests. Those limits are referred to in this paper as the "1979 ICAO Limits."

At the seventh meeting of the Committee (CAN/7), the maximum noise limits for helicopters were relaxed by 3 EPNdB (Ref. 2). This was done primarily because a large percentage of helicopters for which noise data were available did not comply and the economic impact of compliance was too severe (Ref. 3). The new limits became applicable to all applications for airworthiness certificates and changes in type design. The latter applications were restricted to type design changes that had a significant effect on the noise characteristics of the helicopter. CAN/7 also deleted the provision known as "no-noisier-than-parent" for type design changes where the parent helicopter's noise levels exceed the limits, refined some of the reference test windows, and introduced an optional source noise adjustment for the flyover case.

After CAN/7, ICAO expanded the Committee's role to include all provisions relating to environmental aspects of aviation. At the first meeting of the new Committee on Aviation Environmental Protection (CAEP/1), numerous provisions were adopted that significantly altered the helicopter noise certification procedures (Ref. 4). These adversely affected certain type design changes and increased the complexity, hence cost, of compliance with the standards. Among those provisions, the more prominent ones are

1. Expanding applicability of the standards to all changes in type design, even those where there is no increase in noise or where there is an actual noise decrease (became applicable on 17 November 1988).

2. Deleting the "no correction" test windows in which adjustments from test to reference conditions are not required.

3. Introducing use of sensitivity curves or equivalent methods to make the adjustments.

4. Making source noise adjustments mandatory for the flyover case.

Since CAEP/1, the Committee's Working Groups have reversed the trend toward more complexity by developing recommendations for reducing noise certification costs. At the second meeting of the Committee (CAEP/2), one recommendation adopted reverses the first provision listed above, and reinstates the philosophy that a modified design should only be required to be noise certificated when there is an adverse change in the net noise emission. Also, a new Chapter 11 noise standard was adopted for helicopters not exceeding 2,730 kg (6,000 lb) maximum certificated takeoff mass (Ref. 5). An applicant may alternatively elect to show compliance using this chapter's simplified noise test. To date, the USA is the only nation to implement this alternate noise standard for light helicopters. FAR Part 36, Appendix J was promulgated as a final rule, effective September 11, 1992 (Ref. 6).

Implementation

To date, nine countries have promulgated national regulations which incorporate or parallel the ICAO noise standards. Figure 1 depicts when each country issued its regulation, what limits are required, which helicopter designs the regulation applies to, and any additional operational restrictions imposed.

In late 1979, France was the first certification authority to issue a helicopter noise regulation. Subsequently, similar regulations were applied by Austria in 1982, by Switzerland in 1984, by Australia in 1984, by the Netherlands in 1985, by the U.K. in 1986, by Germany in 1987, and by the USA and Canada in 1988. All nine countries apply their regulations to new designs and to changes in type design. Three countries(Australia, the Netherlands, and Germany) apply noise regulation to additions to registry. Two countries (Austria and Switzerland) impose the 1979 ICAO limits which are 3 EPNdB more stringent than the current limits. One country (Switzerland) also places operational restrictions on helicopters in designated areas.

With the exception of the USA, all the above countries have, with minor differences, based their national regulations directly on ICAO Annex 16, Chapter 8. The USA rule (Ref. 7), embodied in FAR Part 36, Appendix H, is identical to that of ICAO as regards maximum noise limits and reference test procedures. However, there are substantive differences in the USA rule, primarily as regards applicability, noise testing requirements, and detailed data correction procedures (Ref. 8).

Noise certification became a requirement to all type certification actions applied for after the effective date of each country's national rule. The large helicopter manufacturers were the first applicants to be affected. For example, in 1986, Eurocopter - France was the first manufacturer to conduct a full noise certification test, that of the AS 350 B1 helicopter. To a large degree, all the large manufacturers were prepared to meet the noise requirements, not only in capital investments expended to conduct compliance testing, but also in reducing noise in the helicopter design process (the primary aim of noise certification).

However, as the rules began to be implemented, other segments of the helicopter industry became affected—namely the small helicopter manufacturers and the helicopter upgrade/modification firms.

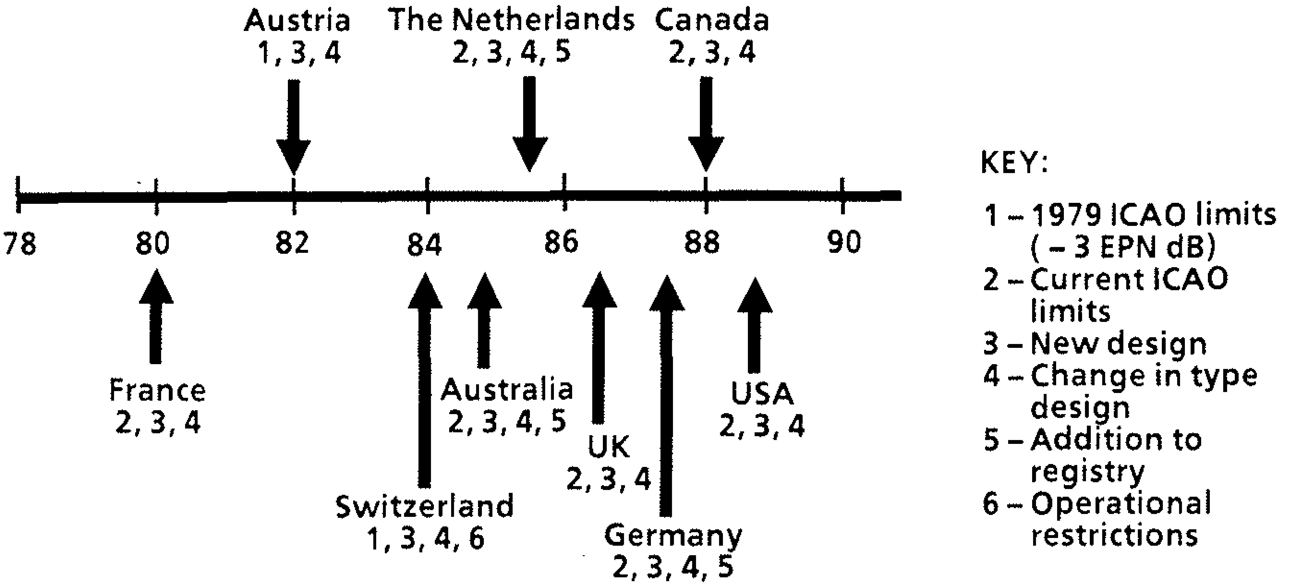

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Fig. 1. Helicopter noise regulations promulgated worldwide.

Most of these manufacturers and firms, primarily located in the USA, were not aware of the development of noise standards nor of the rules' implications on their businesses. As a consequence, they have had to face a relatively new, and disproportionately expensive, requirement in obtaining airworthiness approvals.

Requirements

Meeting the requirements of helicopter noise certification regulations involves a complex process. In a typical process (Fig. 2), schedules of aircraft and manpower, instrumentation buildup, and a test site must be prepared. The noise test must be coordinated with and witnessed by the civil authorities, and it must follow an approved test plan at an acceptable surveyed site. The test aircraft must be instrumented and the flight track, meteorological conditions, and noise levels must be synchronously recorded. The test aircraft must be flown along three different flight profiles over a three-microphone array, and all data must be monitored on-line. Post-test data processing involves use of an approved computer

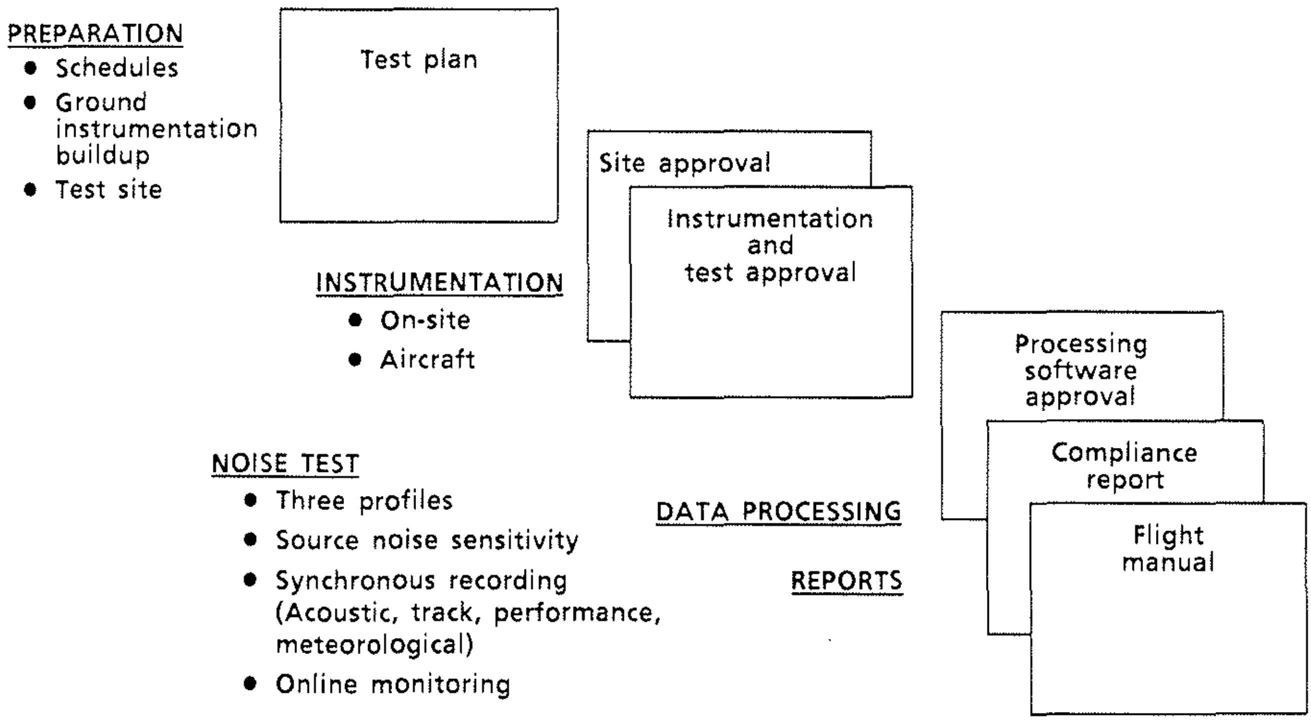

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Fig. 2. Helicopter noise certification process.

program which performs the required corrections of all test data to reference conditions. Finally, a compliance report must be submitted for approval, and all requirements must be met before airworthiness approval is given. The approved noise levels must then be added to the flight manual.

The specific requirements of helicopter noise certification are numerous and detailed. They are summarized in the Appendix. Some of the costlier requirements are

1. Multiple instrumentation systems to measure aircraft performance, flight track, meteorological conditions, and acoustical data must be used to meet standards for data accuracy and quality.

2. The test aircraft must fly three reference flight profiles: takeoff, flyover, and approach. Each profile must be within prescribed test windows of gross weight, airspeed, rotor speed, altitude, zenith, glideslope, and test day temperature, relative humidity, wind speed, cross wind, and air turbulence.

3. Enough passes must be flown to ensure that a minimum of six passes of each profile occur within all test windows.

4. Additional passes must be made to generate parametric or source noise sensitivity curves.

5. Measured data from each instrumentation system must be processed by prescribed methods.

6. Finally, detailed corrections/adjustments must be made to the measured noise levels.

Noise Compliance Experience

In the timeframe during which countries promulgated helicopter noise certification regulations, few new and derivative helicopter developments were undertaken. This was caused by the "downturn" in civil helicopter business in the 1980's. Since early 1989, however, there has been a substantial increase in the number of applications for noise certification. Of the noise certification programs completed to date, all the helicopter models tested are in compliance. Each program, however, has proven to be costly.

Noise Certification Applications

Applications for noise certification have been made or are pending by nine helicopter manufacturers worldwide and at least one modification /conversion firm in the USA. They involve 37 different helicopter models which comprise six new designs, 28 derived versions, and three existing designs.

Full noise certification tests have been completed on 23 helicopters (Refs. 9–12). Noise certification testing of two other models are scheduled or planned in the 1993 – 1995 time period. To date,noise certification has been approved on 25 helicopter models manufactured by Agusta, Eurocopter – Deutschland, Eurocopter – France, Bell, McDonnell Douglas (MDHC), and Sikorsky. Four of these models have been certificated by analysis using approved noise data taken during testing of the acoustically similar parent. Enstrom, Robinson, Schweizer, and Tridair/Soloy Corporations have noise certificated five helicopter models under FAR Part 36, Appendix J in the USA. Six certificating authorities, the FAA (USA), CAA (United Kingdom), DGAC (France), LBA (Germany), FOCA (Switzerland), and TCA (Canada), have issued noise certification approvals.

Certificated Noise Levels

Of the applications made for noise certification to date, noise levels are available for 25 civil helicopters. These helicopters typically represent the latest versions of each model series. The noise levels derived from full noise certification testing are plotted in Fig. 3 for flyover, takeoff, and approach. The current and 1979 ICAO limits for each flight condition are also shown. As can be seen, the noise levels for all 25 helicopters are below the current limits. In general, the margins of compliance are larger for the flyover condition than for takeoff and approach. The smallest margins occur in the approach condition.

Table 1 lists these compliance margins relative to the current ICAO limits for each helicopter model. The average compliance margins for all models and for two weight categories are also shown. On an individual basis, one helicopter's compliance margins range as high as 4.9 to 10.6 EPNdB. In contrast, another helicopter's margins range as low as 0.6 to 3.1 EPNdB. Collectively, the average margins for all the helicopters range from 2.7 to 4.7 EPNdB.

Relative to the 1979 ICAO noise limits, the compliance margins of Table 1 are reduced by 3 EPNdB for all weight categories. If these limits were reintroduced, six of the 25 helicopter models would no longer comply. Twelve other models exceed the 1979 limits at one, or in some case, two flight conditions, but would just comply, using permitted tradeoffs.

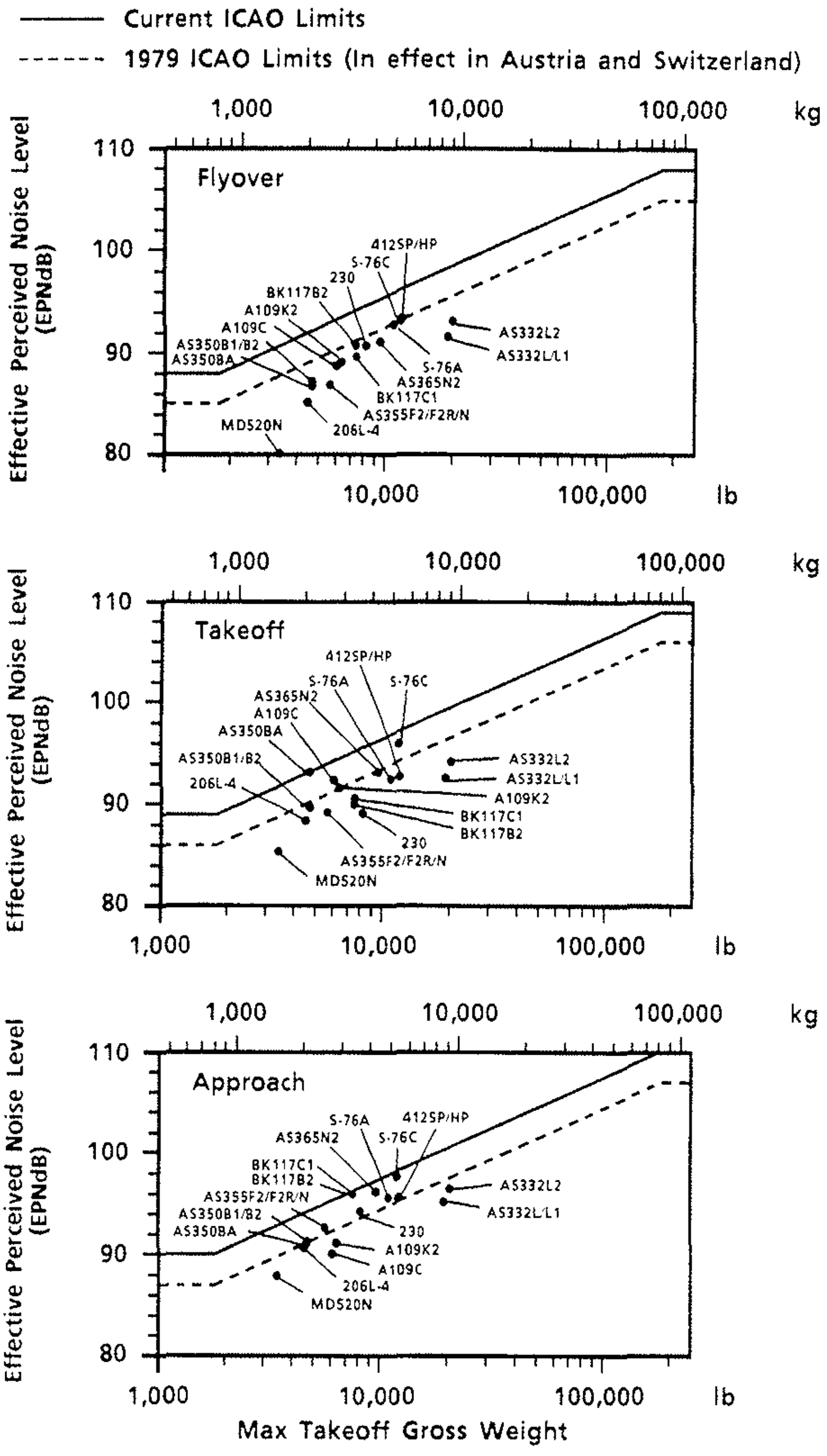

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Fig. 3. Certificated noise levels of civil helicopters.

Costs

Helicopter noise certification is expensive, primarily because meeting current requirements is a complex process. The relatively high costs are traceable to the sophistication of the instrumentation systems used, the noise test itself (including aircraft costs), and the data processing.

Original estimates of helicopter noise certification costs by the manufacturers (Ref. 3), prior to full noise test experience, ranged from $60,000 to

Table 1. **Margin of compliance with current ICAO noise limits of noise-certificated civil helicopters**

Helicopter model	Weight (kg/lb)	Compliance Margin (EPNdB)		
		Flyover	Takeoff	Approach
≤2,722 kg/6,000 lb				
500ER*	1,360/3,000	3.6	3.7	2.0
500N	1,520/3,350	10.6	6.4	4.9
206L-4	2,018/4,450	6.7	4.8	3.3
AS 350 BA	2,100/4,630	4.9	0.0	2.9
AS 350 B1	2,200/4,850	5.1	3.7	3.1
AS 350 B2	2,250/4,960	4.9	3.7	3.1
AS 355 F2	2,540/5,600	5.0	5.3	1.7
AS 355 F2 R	2,540/5,600	5.4	5.0	1.2
AS 355 N	2,540/5,600	6.4	5.4	2.3
A 109 C	2,720/5,998	4.6	2.0	5.3
	AVG:	5.7	4.0	3.0
≥2,722 kg/6,000 lb				
A 109 K2	2,850/6,284	4.5	2.9	4.5
BK 117 B2	3,350/7,417	3.0	5.4	0.5
BK 117 C1	3,350/7,417	3.1	4.6	0.2
230 (wheel gear)	3,810/8,400	3.9	6.7	2.5
230 (skid gear)	3,810/8,400	4.2	6.7	2.5
AS 365 N2	4,250/9,370	4.1	3.1	1.1
S-76A	4,898/10,800	3.1	4.1	2.4
S-76A (STC)	4,898/10,800	3.3	4.6	1.8
S-76C	5,306/11,700	3.1	1.3	0.6
S-76C (STC)	5,306/11,700	3.4	1.1	0.5
412SP	5,397/11,900	2.9	4.1	2.7
412HP	5,397/11,900	2.9	4.5	2.7
AS 332 L	8,350/18,412	7.4	7.5	5.8
AS 332 L1	8,602/18,967	6.7	6.7	5.1
AS 332 L2	9,150/20,176	5.0	5.4	4.5
	AVG:	4.0	4.6	2.5
All Models	AVG:	4.7	4.3	2.7

*Approval of the McDonnell Douglas 500 ER is pending.

$200,000 (U.S. dollars,1987/1988 rates). In the process of promulgating national regulations, some civil authorities estimated the costs to range between $5,000 and $50,000. As it turns out, both the manufacturers' and the civil authorities' estimates were low.

Table 2 summarizes the actual recurring costs of nine noise-certification programs completed to date. Actual recurring costs to noise-certificate a baseline helicopter model range from $121,000 to $600,000 (U.S. dollars, 1989/1990 rates). The average cost to noise-certificate one baseline helicopter is $275,000. As remarked in the table, the costs of noise-certifying some models are significantly reduced when more than one configuration can be tested at the same time or when additional flights are made by the baseline test aircraft configured to

Table 2. Costs of helicopter noise certification test programs

Manufacturer	Helicopter Model	Certification procedure used / date approved	Actual Costs (U.S. dollars,1989/1990 rates), thousands ($K)	Remarks
Eurocopter - France	AS 365 N2	ICAO/1990 FAR/1990	209	Weather equipment for altitude tests provided by DGAC; final certification approval given by DGAC
	AS 355 F2R	ICAO/1991 FAR/1991	146	Weather equipment for altitude tests provided by DGAC; final certification approval given by DGAC
	AS 332 L2	ICAO/1992 FAR/1992	243	Weather equipment for altitude tests provided by DGAC; final certification approval given by DGAC
Agusta	A109C	ICAO/1992	170	Test completed; final certification approval given; includes partial budgetary costs
Sikorsky	S-76A	FAR/1989 ICAO/1989	600	FAA and CAA approved. $5.4K additional costs for FAA approval of S-76A(STC)
	S-76C	FAR/1990 ICAO/1991	271	FAA and CAA approved. $4.6K additional costs for FAA approval of S-76C(STC)
MDHC	500N	FAR/1991 ICAO/	239	FAA approved
	500ER	FAR/ ICAO/	121	Tests completed; final certification approval not yet given; shared costs with 500N test
Bell	412SP	FAR/1991	479	FAA approved; $95K additional costs for FAA approval of 412HP

acoustically represent a growth version. In these cases, the costs are shared in test preparation, instrumentation buildup and tear down, and aircraft expenses.

For the above nine noise certification programs, the total recurring costs incurred by the helicopter manufacturers amount to approximately $2.7 million. These costs are two to three times higher than originally estimated by the manufacturers, and are from 10 to over 100 times higher than estimated by civil authorities.

A breakdown of the above recurring costs is presented in Table 3. Actual costs are shown for six tasks: test preparation, site instrumentation, aircraft instrumentation, test, data processing, and reports. Table 3 reveals the following:

1. The most costly tasks are the aircraft and site instrumentation, the test itself, and the data processing. These tasks average 25%, 38%, and 21% of the total program costs, respectively.

2. Aircraft instrumentation costs vary depending on whether automated aircraft position tracking (e.g., microwave or laser systems) is used to satisfy the certification procedure and to verify during each flight pass that all test windows are met. Also, configuring an uninstrumented production aircraft for use as the test vehicle, then returning it to the production configuration after the noise test, adds to the costs.

3. Tests costs are driven up by the large number of flight passes necessary to stay within all test windows and to gather source noise correction data. Also, the larger helicopters are more expensive to operate.

4. Data processing costs are relatively high because of the large number of data points to be processed, the numerous corrections to be made, and the computerized one-half second, third octave analyses required.

The large variation in reported costs is the result of many factors, some unique to where and when the helicopter is tested, while others relate to how each manufacturer accounts the costs. In addition to the factors mentioned in (2) and (3) above, noise tests conducted to comply with FAA regulations are more expensive than those conducted exclusively to meet ICAO Annex 16. At least two noise test programs experienced marginal meteorological conditions over a two- to four-week test period. In some programs, the manufacturers charged the total aircraft costs to the noise test, while others distributed portions of the costs to the helicopter's primary airworthiness testing.

Table 3. Cost breakdown of helicopter noise certification test programs

	Eurocopter – France			Agusta	Bell	MDHC		Sikorsky	
	AS335F2R	AS365N2	AS332L2	A109C	412SP	500N	500ER	S-76A	S-76C
Test preparation	7,000	7,000	7,000	32,072	54,458	17,340	2,400	38,600	24,800
Site instrumentation	43,200	43,200	43,200	(included below)	58,136	16,200	4,200	78,200	39,600
Aircraft instrumentation	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		122,217	148,810	85,310	244,300	108,100
Data processing	53,720	59,520	59,520	132,363	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
Totals	$146,390	$209,320	$242,920	$170,000 (partial)	$478,573	$239,350	$121,310	$599,900	$271,100

In addition to the recurring costs, there are significant nonrecurring costs. These are mainly capital investments in facilities,instrumentation, and equipment necessary to conduct noise certification test programs. As reported by the manufacturers, these nonrecurring costs range from $600,000 to $1.0 million U.S. dollars per company.

Compliance Cost Reductions

Over the last 25 years, the subsonic jet and propeller-driven airplane industries gained extensive noise certification test experience. From this experience, improvements in those aircraft noise standards have evolved that reduce the amount of testing and establish accurate equivalences. Similar experience, just beginning in the rotorcraft industry, supports needed improvements and simplifications in helicopter noise standards. Such improvements and simplifications are the only way that the costs of noise certification can be reduced while maintaining data accuracy and test validity.

Ongoing studies within ICAO, in various member states, and by industry have identified a number of viable improvements in the noise standards procedures. These improvements fall into three broad categories: a simplified certification scheme, less complex procedures for noise testing and data adjustments, and less rigid "acoustical change" provisions affecting derived versions and upgrades/modifications to production helicopters. Each improvement is discussed below.

Simplified Certification Scheme

As mentioned previously, ICAO CAEP/2 adopted a proposed amendment to Annex 16 establishing a screening method for "light" helicopters. This development is in view of the higher relative cost to noise-certificate smaller helicopters as compared to their sales price and airworthiness certification costs.

As currently proposed within ICAO, an applicant could choose to noise-certificate using the screening method and, if compliance is shown, would not be required to meet further requirements. That is, helicopters that comply would be considered to have demonstrated compliance with Chapter 8. If compliance is not shown, the applicant can conduct the full Chapter 8 noise test. Use of the method is restricted to "light" helicopters with a maximum takeoff weight of 2,730 kg (6,000 lb) or less.

When approved by ICAO member states, a new Chapter 11 and Appendix 7 will be implemented as the "screening test." Chapter 11/Appendix 7 describe a relatively simple noise test: a level flight condition, four passes, one microphone, the SEL noise metric, and minimal data corrections. At the same time, the noise limit for the single level-flight condition is equivalently 3 to 4 dB more stringent than that of Chapter 8. Also, there is no provision for tradeoffs in Chapter 11/Appendix 7.

Less Complex Procedures

Conducting the flight test has been shown to be one of the main costs of noise certification. Also, performing detailed analysis of the data is another main cost, in particular the number of data corrections that must be made.

Simplifications of the current noise certification standards' procedures include

1. Use of an altitude zero adjustment test window of ±10 m for flyover and approach. (If a flight pass is in this test window, no correction to the data would be required.)

2. Elimination of the "ground speed" correction requirement, replacing it with the requirement to conduct takeoff and approach tests into wind and to conduct flyover tests in equal numbers with tail and head wind. (Testing into wind is a normal flight test safety requirement on takeoff and approach.)

3. Use of a temperature/humidity zero-absorption adjustment window. (Similar to above, if a flight pass is in this meteorological window, no correction to the data would be required.)

4. Replacement of the current mandatory source noise correction for flyover, by testing at a "Mach equivalent" reference airspeed. (This will reduce the number of flyover flights necessary by 60% to 80%. The applicant could still opt to test at different airspeeds to obtain a sensitivity curve for use in future derived versions.)

5. Application of a simple distance correction for the case where the test distances depart from the reference distance by more than ±10 m.

The above simplifications are based on the fact that, except for the distance term,the differences between the "fully corrected" noise levels and the "as-measured" noise levels are typically no more than 0.2 to 0.3 EPNdB. The aforementioned certification tests completed to date verify this fact. These small corrections result because the majority of the testing is carried out well within the allowable temperature/humidity and flight speed "test windows." The net result of these simplifications is that flyover passes would be drastically reduced, no ground speed measurements would be required, and only a simple distance correction would need be applied to the "as-measured" data.

Any simplification could result in some reduction in accuracy. A 0.2- to 0.3-EPNdB "error" is not unrealistic, particularly when the repeatability of measurement/analysis of data points is no better than ±1.5 EPNdB (Ref. 13).

In implementing such simplifications, consideration of making them optional has merit. That's because the certification authority may opt to accept the simplifications only if the final quoted noise level (which is the average of several data points) is 0.3 EPNdB or more below the limit for each flight condition considered. This consideration is realistic since, if the final level is projected to be that close to the limit, the applicant would most likely not choose the option because of fear of failure.

Less Rigid Applicability Requirements

The applicability requirements of helicopter noise standards dealing with a change in type design and acoustical changes need to be less rigid. This is because numerous changes are made in a helicopter model series, by both the manufacturer and by upgrade/modification firms, and the costs of repeated noise certification testing of every change are exorbitant.

It is the industry's understanding that ICAO did not originally intend to require recertification each time minor or insignificant changes are made to a noise-certificated parent helicopter. Such changes include "add-on" kits and equipment, e.g., external searchlights, steps, hoists, fuel tanks, and mirrors. Also included are certain replacement parts, such as bubble side windows. Currently, some nations do not require additional noise tests of helicopters equipped with such add-ons, whereas others require full noise certification tests for each case.

Clearly, clarification and agreement are needed as to what constitutes a "change in type design" and what constitutes "acoustical change." In principle, this can be accomplished in several ways:

1. Changing the applicability requirements of noise standards so that recertification is necessary only when substantial changes or modifications, in airworthiness terms, are made to the helicopter.

2. Exempt from recertification any add-on kit/equipment or replacement part that does not involve a design change of the basic airframe.

3. Redefine an "acoustical change" as a net increase in noise level of 1.0 EPNdB, due to a change or modification, determined by data or analyses acceptable to the certificating authority.

Equivalent accuracy and stringency are maintained by the foregoing proposals. Additionally, they can be implemented for all categories of helicopters regardless of weight.

Concluding Remarks

Compliance with current noise certification requirements for helicopters has proved to be a more involved process than originally envisioned, either by the civil authorities or by the industry. The costs being experienced by applicants conducting certification programs are high, even for the large helicopter manufacturers. For the small manufacturers faced with noise certification, these costs can be equal to or exceed the total costs incurred for airworthiness certification alone. To a largely forgotten but very vital segment of the industry, such costs are *prohibitive* for small businesses specializing in helicopter upgrades and modifications. Prior to mid-1992 in the USA, where almost all such business takes place, applicants have opted for FAA Stage 1 or curtailed the extent of their STC or proposed to the FAA a lower-cost noise test. In other instances, applicants have abandoned the planned STC because of the projected cost of noise certification. Since September 1992, the use of FAR Part 36, Appendix J has significantly reduced the cost of noise certification of light helicopters. Adoption of the similar new Annex 16, Chapter 11 noise standard by all ICAO member states is urgently needed.

Cooperative efforts are underway to remove needless complexity, hence reduce the costs, of the noise certification process. All segments of the industry and the civil authorities are aware of the need to improve the current standards. The three simplifications discussed in this paper, i.e., a simplified certification scheme, less complex procedures, and less rigid applicability requirements, are realistic ways to accomplish this. The challenge is to expeditiously make the necessary improvements.

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Appendix
Helicopter Noise Certification Requirements

The requirements of helicopter noise certification are summarized below with regard to applicability, instrumentation, testing, and data processing. While most of the requirements reviewed are the same in all countries with noise rules, implementation has proved to be different. Hence, the present review will be limited to the authors' experience with the USA's FAR Part 36.

Applicability

In the USA, FAR Part 36 affects issuances of original and amended type certificates applied for by manufacturers, and supplemental type certificates (STC) applied for by upgrade/modification firms. Only helicopter models designated exclusively for agricultural operations, for dispensing firefighting materials, or for carrying external loads are exempt.

All new designs, all derivatives of new designs, and most changes to existing designs must be noise certificated. Noise certification requirements must be met before airworthiness approval is given. Only certain changes in type design that are shown to be "no-noisier-than-parent," determined by the FAA, can comply without a noise certificate. Older existing designs do not require a noise certificate. However, export sales to an increasing number of countries require that these existing designs also be noise certificated. In one country, France, higher landing fees can be assessed to operators whose helicopters do not have noise certificates.

Instrumentation

Multiple instrumentation systems must be used to meet data accuracy and quality standards. The test aircraft must be instrumented to measure and record basic performance parameters, e.g., airspeed, rpm, and torque. Aircraft position tracking equipment must also be installed. Depending on the tracking system used to satisfy the requirements, extensive instrumentation can include a microwave transponder, analysis package/encoder/telemetry transmitter, ILS indicator (pilot aid to intersect and follow reference flight profiles), and antennas.

At the test site, primary instrumentation systems are required to record noise level time histories of a three-microphone array, to synchronously document the aircraft position track, and to measure meteorological conditions. The latter includes measurements of wind speed, wind direction, temperature, and relative humidity at 10 m of height and at reference flight altitudes (this necessitates use of a sensor/telemetry system carried aloft, typically by a tethered balloon).

Testing

An applicant must show compliance with maximum noise limits for three reference flight procedures: takeoff, flyover, and approach. Fig. A-1 depicts the three reference flight procedures and microphone measurement locations required in helicopter noise certification testing. The test aircraft must fly each flight procedure, be within prescribed test windows, and make enough passes to ensure that a minimum of six passes in each procedure are within all test windows.

In the takeoff procedure, the test aircraft approaches the microphone array at an altitude of 65 ft (20 m) and V_Y airspeed (speed for best rate of climb). At a predetermined "takeoff point," typically 1640 ft (500 m) uprange of the microphone array, a climb is initiated at maximum takeoff power while maintaining V_Y airspeed. The steady climb is continued until the aircraft is well out of range.

The flyover procedure is conducted at a level flight altitude of 492 ft (150 m) at 0.9 V_H or 0.9 V_{NE}, whichever is lower. For noise certification purposes, V_H is defined as the power-limited airspeed and V_{NE} is the not-to-exceed airspeed. As in the takeoff case, the steady level flyover is continued until the noise is well below the maximum level. Additional flyovers at up to four other airspeeds are required to generate parametric noise sensitivity curves.

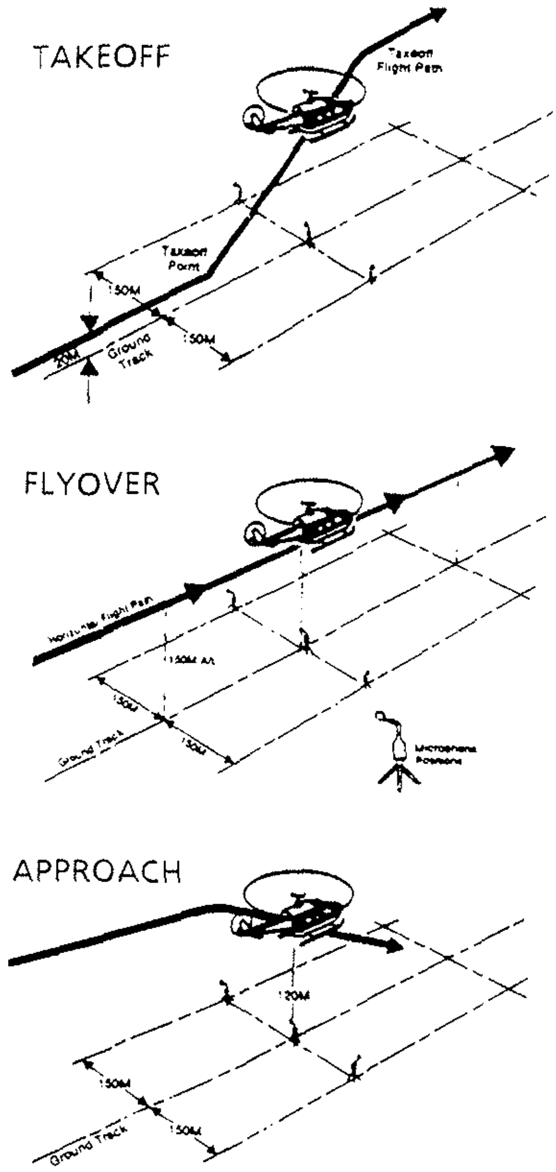

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Fig. A-1. Noise certification flight procedures and measurement locations.

In the approach procedure, the test aircraft intersects a projected 6-deg glideslope. It then follows that glideslope at constant V_Y airspeed, passes over the center microphone at a reference altitude of 394 ft (120 m), and continues the steady approach down to a minimum altitude before breaking off.

Each pass flown attempts to follow the specified flight procedures and to simultaneously satisfy all prescribed test windows, i.e., allowable deviations of test parameters from reference conditions. These test windows are extensive and must be monitored during testing. They are listed in Table A-1.

Table A-1. Test windows and allowable deviations from reference conditions

Conditions	Test Window
Aircraft:	
Gross weight[1]	+5%, −10% (of max. internal gross weight)
Airspeed	±5 kn
Rotor speed	±1% (of 100% rpm)
Altitude[2]	±30 ft (flyover, approach)
Zenith	±10° (takeoff,approach) ±5° (flyover)
Glideslope	6° ± 0.5° (approach)
Meteorological:	
Atmospheric	No rain or other precipitation
Temperature	36°F to 95°F/2.2°C to 35°C
Relative humidity	20% to 95%
Attenuation[3]	$\leq$12 dB per 100 m / $\leq$ 36.6 dB per 1000 ft
Wind speed	$\leq$10 kn (at 10 m)
Crosswind	$\leq$5 kn (at 10 m)
Headwind[4]	$\leq$10 kn (at 500 ft)
Turbulence, etc.	No anomalous wind conditions over the sound propagation path

[1] At least one "acceptable pass must be conducted at a weight above 100% maximum internal weight.

[2] Each takeoff pass must be within a predetermined distance of the reference altitude at PNLTM.

[3] In 1/3- octave band centered at 8 kHz.

[4] Applicable to flyover only.

Data Processing

The aircraft performance, tracking, meteorological, and acoustical data must be processed by prescribed methods. Then detailed corrections/adjustments must be made to the measured noise levels.

The primary purpose of post-test data processing is to extract the test aircraft's as-measured noise levels, then correct those levels back to reference conditions. Time-history recordings of aircraft tracking data, aircraft performance data, meteorological measurements at ground level and at the aircraft altitude, and acoustical data from the three microphones are each processed separately and stored in digital format. Assuming a microwave tracking system is used, range data from the aircraft tracking system is first converted to x,y,z coordinates using a least-squares algorithm. Aircraft performance data are then converted to engineering units and averaged over the 10-dB downtime period of each flight. Similarly, meteorological data are averaged over the 10-dB downtime period. Analog acoustical recordings are converted to a time history of 1/3-octave sound levels at 1/2-second intervals.

A computer program reads all data streams and synchronously matches them. The aircraft performance and track, and the meteorological data are examined to verify that they are within prescribed limits. Amplitude and frequency corrections are applied to the acoustical data. Using the meteorological data, the acoustical data are then corrected to reference standard day conditions. The acoustical levels are further adjusted for deviations of the aircraft flight tracks from reference flight tracks. For the flyover case, an additional adjustment is made using a source noise correction procedure.