EIGHTH EUROPEAN ROTORCRAFT AND POWERED LIFT AIRCRAFT FORUM

Paper No. 9.4

HELICOPTER EXTERNAL NOISE: ICAO STANDARDS AND OPERATIONAL REGULATIONS

by

H.J. MARZE

Société Nationale Industrielle Aérospatiale

Helicopter Division

Marignane, France

August 31 / September 3, 1982

AIX-EN-PROVENCE

FRANCE

ASSOCIATION AERONAUTIQUE & ASTRONAUTIQUE DE FRANCE

HELICOPTER EXTERNAL NOISE:
ICAO STANDARDS AND OPERATIONAL REGULATIONS

by
H.J. MARZE
Société Nationale Industrielle Aérospatiale

Helicopter Division
Marignane, France

Preliminary Remark

This paper does not represent AEROSPATIALE'S point of view; it should rather be considered a general review of the problems inherent to external noise regulations for helicopters.

1. INTRODUCTION

In the last few years, the helicopter has proved its unique capability to execute various civil missions and, particularly, to transport passengers or loads in the very center of towns.

The civil market is thus expanding rapidly (See development forecasts on fig. 1). The increase in number of aircraft and operators has enlarged the number of operations on existing heliports and led to a request for new heliports in urban areas.

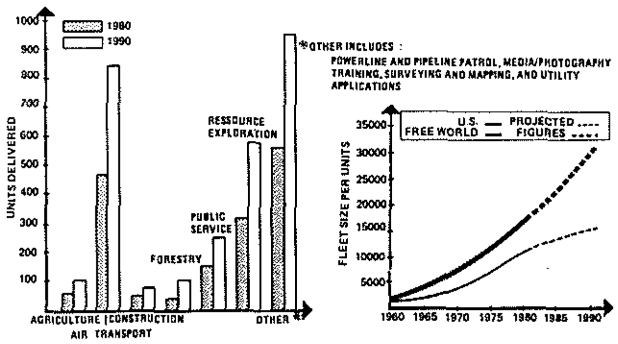

Fig. 1 : HELICOPTER MARKET FORECAST

Consequently, it *is not* surprising that, as early as 1974, ICAO decided to look into helicopter noise problems and appointed an International Working Group to establish a helicopter noise certification scheme.

A certification draft applicable to new-design and derived-version helicopters was adopted during ICAO's CAN 6 meeting in May 1979. Working Group B (WGB) was then required to refine and extend the approved certification standard to all helicopter types.

WGB work is now over and conclusions are being sent to ICAO for further discussions at CAN 7 1983 *meeting*. In the WGB conclusions, one notes that :

1) application of any noise certification regulation to helicopters is being questioned by one of the member states.

2) application of the standard to future production of existing helicopter types was premature.

Furthermore, it would seem that the aptitude of the standard to ensure immediate protection of urban *environment from noisy helicopter* invasion is not recognized by local lobbies, town councils and even official bodies such as the Office Fédéral de l'Air Suisse.

The preceding points have led to the enforcement of local operational regulations including major restrictions of helicopter activities.

To save the helicopter industry and operators from operational restrictions resulting from multiplication of local (town or country) regulations, the Helicopter Association International (HAI) suggested that a program of studies be developed to reduce noise nuisance perceived on ground. This program would be applied to every helicopter type including future new designs, derived versions, current production and helicopters already in operation.

Noise would be reduced by modifying piloting techniques and crew training methods. Every party *concerned* (manufacturers, operators, pilots, environment protection groups, certification authorities, local councils, national organizations.....) would be involved in the development of this project.

In this document,

i) The main features of the ICAO scheme and the aptitude of such regulations to protect the environment are reviewed.

ii) The advantages and drawbacks of local authorities' *regulations and, particularly,* the potential consequences for manufacturers and operators are examined.

iii) It is finally shown that the multiplication of differing regulations i.e. ICAO international standard, local or national operational regulations...... could be a real danger for helicopter manufacturers and operators if these regulations are not drafted in harmony.

2. ICAO STANDARDS

Hereunder are examined the ICAO standard as per CAN 6 and WGB suggestions to be discussed during CAN 7 (1983)

ICAO standard defines three reference flight procedures. Noise is measured with three microphones in each flight procedure. Noise limits, function of helicopter mass, are set for each flight procedure.

2.1 REFERENCE FLIGHT PROCEDURES

a) Flyover reference procedure (Fig. 2)

The helicopter shall be stabilized at a height of 150 m and a speed of 0.9 VH or 0.9 VNE or (0.45 VH + 120 km/h) or (0.45 VNE + 120 km/h) whichever is the lower value.

b) Take-off reference procedure (Fig. 3)

The helicopter shall be stabilized at the maximum take-off power and the best rate of climb along a path starting from a point located 500 m forward of the microphone and 20 m above ground. Speed is VY or the lowest approved take-off speed whichever is the greater.

c) Approach reference procedure (Fig. 4)

The helicopter shall be stabilized along a 6 ° approach path at speed VY or at the lowest speed approved for approach whichever is the greater

- The helicopter mass shall be the maximum take-off mass at which noise certification is requested.

The maximum operating RPM shall be considered the maximum value in the normal operating range for each procedure.

- Reference weather conditions 10 m above ground are :

Temperature : 25 ° C (or 15 ° C depending upon agreement with certification authorities)
Relative humidity : 70 %
Pressure : 1025 bar
Wind : nil

ICAO REFERENCE PROCEDURES

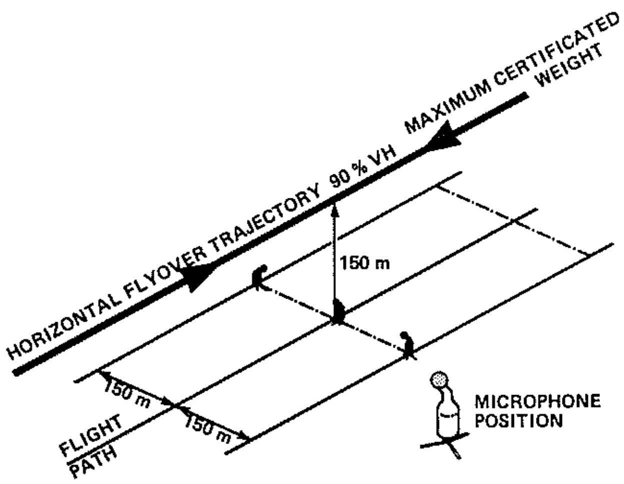

Fig. 2 : FLYOVER TRAJECTORY

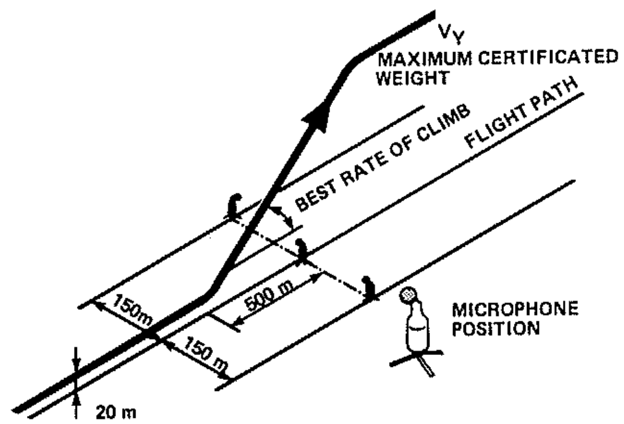

Fig. 3 : TAKE-OFF TRAJECTORY

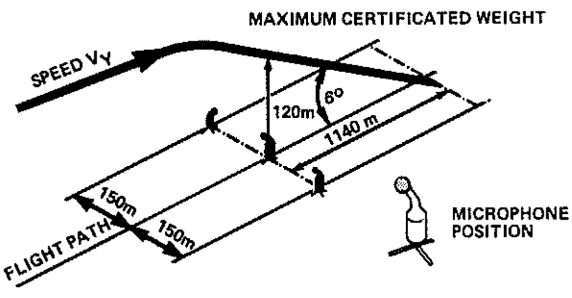

Fig. 4 : LANDING TRAJECTORY

2.2. POSITION OF MICROPHONES

Three microphones will be used with each flight path : One located under the flight path track and two laterally, 150 m to the left and right of flight path track on ground.
During take-off (see fig. 3), the center microphone is 500 m away from initial climb point.

During approach (see fig. 4), the center microphone is located 1140 m away from touchdown (120 m under flight path)

2.3. NOISE LEVEL UNITS

Noise levels are measured in EPNdB with each microphone. The arithmetical mean of measurements recorded over the three microphones defines noise level applicable to the flight path considered.
Each measurement is repeated six times to obtain a mean whose 90% confidence limit is lower than plus or minus 1.5 EPNdB for each flight path.

The effects of pure sounds that may be present in noise spectra and the effects of duration are corrected in perceived noise level (EPNL). Up to now, no impulsion correction could be defined for Working Group B.

2.4. LIMIT LEVELS AND APPLICABILITY (see fig. 5 and 6)

2.4.1. Draft approved during CAN 6 meeting in 1979

a) New designs

Depending upon aircraft mass, three limits were determined for each flight path (see fig. 5)

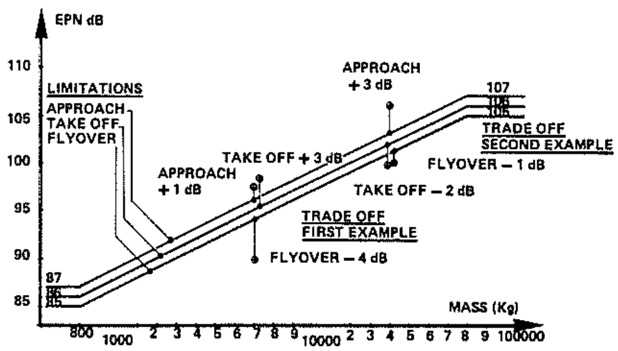

Fig. 5 : ICAO NOISE LIMITATIONS

FLIGHT PATH	MASS BELOW 800KG CONSTANT LEVEL	800KG<MASS<80000KG	MASS ABOVE 80000KG CONSTANT LEVEL
Flyover	85 EPNdB	3 EPNdB increase when mass is doubled i.e. a 10 log of mass law.	105 EPNdB
Take-off	86 EPNdB		106 EPNdB
Approach	87 EPNdB		107 EPNdB

b) Derived version helicopters

There are two cases :

- Type certification of basic aircraft was requested after January 1st, 1980 : the derived version is then considered a new design

- Type certification of basic aircraft was requested before Jan.1st, 1980 : as from January 1st, 1985, derived-version helicopters shall not be noisier than basic version if this version exceeds limits or shall not exceed new-design noise limits if basic version is below limits.

c) Trade-off

A 4/3 trade-off has been retained between measured and limit noise levels, trade-off of negative variations and positive variations is allowed with the following limits :
- Maximum excess on one trajectory is 3 dB
- Total excess on two trajectories is 4 dB
(see examples on fig. 5)

2.4.2 Working Group B proposal to CAN 7 (1983)

- One member state,basing their argument on the fact that not enough economic studies have yet been carried out to evaluate the impact of the noise regulation, stated that any helicopter noise regulation is premature and should be postponed until mid 1984.

- Two member states would like to maintain the ICAO CAN 6 noise regulation as it is.

- Three member states would retain the new design rule as it is but would like to change the contents of the regulation applicable to derived versions as follows :

All derived versions, irrespective of the date of request of the parent's certification, would have, as noise limits, the new design limits increased by X dB. Three decibels were considered a reasonable value for X.

- One member state would rather separate the derived versions into two categories :

a) Derived versions of new designs where X additional decibels would be allowed.
b) Derived versions of old designs (Application for type certification before January 1st, 1980) which would be allowed an additional tolerance of Y decibels to the previous X decibels

The main reasons that led the group to propose a modification of the derived-version rule are as follows:
a) The "No Noisier Than Parent" rule is not fair and might maintain noisy helicopters in operation for a long period of time.
b) For a given helicopter, a gross mass increase leads, in general, to a noise increase at a slope much higher than the 10 Log mass law defining the new design noise limits. Some extra decibels should then be allowed to derived versions in order to maintain the potential growth of helicopters

All member states agreed that it was premature to propose any rule for the current production of helicopters.

As regards civil derivatives of military designs, the member states agreed to consider the military parent as equivalent to the civil prototype.

HELICOPTER CLASSIFICATION	ICAO RULE JUNE 1979 ANNEX 16 - CHAP. 8 AND APPENDIX 4	GROUP B PROPOSALS FOR ICAO – CAN 7 1983 (EXCEPT ONE STATE)
1) NEW DESIGNS	• –01 – 01 – 1980 • 3 LIMITS • TRADE OFF 4/3	← SAME AS 1979 RULE
2) DERIVATIVES 2.1. DERIVED VERSIONS OF NEW DESIGN	SAME AS NEW DESIGNS	← NEW DESIGN LIMITS + X dB
2.2 DERIVED VERSIONS OF OLD DESIGN	01 – 01 – 1985 NO NOISIER THAN PARENTS OR NEW DESIGN LIMITS	← NEW DESIGN LIMITS + Y dB
2.3 CIVIL VERSIONS DERIVED FROM MILITARY VERSIONS	SAME AS NEW DESIGN	← NEW DESIGN LIMITS + X dB

Fig. 6 : ICAO RULE

2.5 HELICOPTER NOISE MEASUREMENTS BY GROUP B MEMBERS :

Twenty four types of helicopter (1,000 to 22,000 kg) were thoroughly measured in conditions close to reference conditions set at CAN 6 and ten additional types were partially measured.

Results of measurements for each procedure are given in figures 7, 8 and 9.

Variations between measured values and relevant ICAO limits for the three paths are indicated on fig. 10.

The mean noise levels of the three paths are indicated with respect to 57 + 10 log mass mean limit on fig. 11.

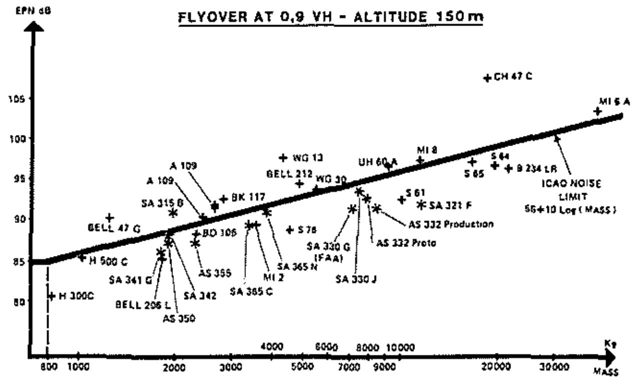

Fig. 7 : HELICOPTER NOISE LEVEL MEASURED IN ICAO FLIGHT CONDITIONS FLYOVER

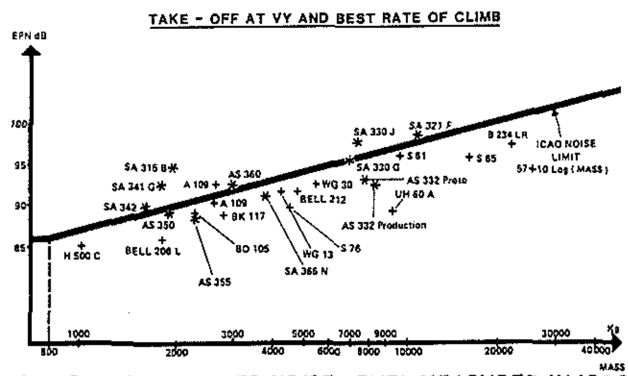

Fig. 8 : HELICOPTER NOISE LEVEL MEASURED IN ICAO FLIGHT CONDITIONS TAKE OFF

Take-off mass kg	Helicopter Type	Variation of noise level with respect to regulations				Trade-off Applicable < Yes / No	Mean value of resulting variation
		Take-off	Approach	Flyover	Total of 3 variations		
818	H 300 C	–	–	– 4.5	–		–
1020	H 500 C	– 2	– 0.4	– 0.3	– 2.7·		– 0.9
1237	Bell 47G	–	+ 0.7	+ 3.4	–		–
1800	SA 341 G	+ 3.1	– 1.0	– 2.4	– 0.3	No	– 0.1
1814	Bell 206L	– 3.7	– 0.3	– 2.8	– 6.8		– 2.3
1900	AS 350 B	– 0.5	+ 0.5	– 1.5	– 1.5	Yes 0.5 dB	– 0.5
1900	SA 342	+ 0.1	+ 4.8	– 0.5	+ 4.4	No	+ 1.5
1950	SA 315 B	+ 4.9	+ 4.0	+ 2.1	+ 11	No	+ 3.7
2300	AS 355	– 2.1	+ 1.3	– 2.4	– 3.2	Yes 1.3 dB	– 1.1
2300	BO 105	– 1.5	+ 0.1	– 1.2	– 2.6	Yes 0.1 dB	– 0.9
2400	A 109		+ 1.1	+ 0.5	–		–
2600	A 109	+ 1.8	+ 3.9	+ 1.6	+ 7	No	+ 2.4
2600	A 109	– 0.9	– 0.8	+ 1.7	0	Yes 1.7 dB	0
2800	BK 117	– 2.7	– 2.1	+ 2.1	– 2.7	Yes 2.1 dB	– 0.9
3000	SA 360	+ 0.7	–	–	–		–
3400	SA 365 C	–	+ 0.7	– 1.9	–		–
3520	MI 2	–	+ 2.7	– 1.9	–		–
3800	SA 365 N	– 1.5	– 1.2	– 0.9	– 3.6		– 1.2
4240	WG 13	– 1.6	+ 2.7	+ 5.5	+ 6.6	No	+ 2.2
4546	S 76	– 3.6	– 2.3	– 3.6	– 9.5	No	– 3.2
4762	Bell 212	– 2	+ 1.0	+ 1.9	+ 0.9	Yes 2.9 dB	+ 0.3
5443	WG 30	– 1.8	+ 2.4	+ 0.3	+ 0.9	No	+ 0.3
7045	SA 330 G	0	– 0.8	– 3	– 3.8		– 1.3
7400	SA 330 J	+ 2.1	– 0.6	– 1.1	+ 0.4	No	+ 0.1
7800	AS 332 proto	– 2.9	– 2.4	– 2.1	– 7.4		– 2.5
8350	AS 332 product.	– 3.7	– 2.1	– 3.7	– 9.5		– 3.2
9185	UH 60A	– 7.4	– 0.7	+ 1.2	– 6.9	Yes 1.2 dB	– 2.3
10000	S 61	– 1.1	– 4	– 3.4	– 8.5		– 2.8
11436	MI 8	–	+ 1.0	+ 0.7	–		–
11500	SA 321 F	+ 0.8	0	– 4.6	– 3.8	Yes 0.8 dB	– 1.3
16783	S-65	– 3.5	– 0.3	– 1.1	– 4.9		– 1.6
18561	CH 47	–	+ 4.7	+ 8.9	–		–
19420	S-64	–	– 2.3	– 2.2	–		–
22000	B 234 LR	– 3.2	+ 0.9	– 3.2	– 5.5	Yes 0.9 dB	– 1.8
40116	MI 6A	–	+ 3.4	+ 1.4	–		–

Fig. 10 : SUMMING UP OF HELICOPTER NOISE LEVELS MEASURED

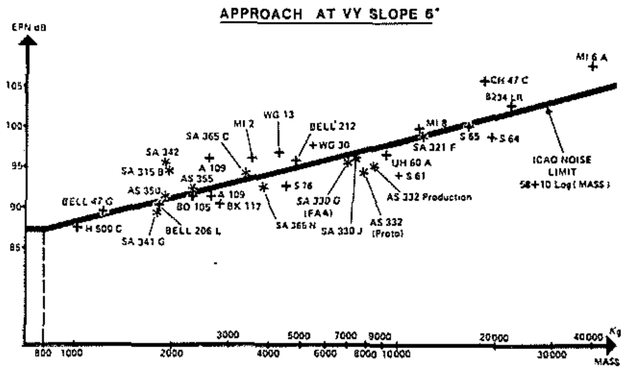

Fig. 9 : HELICOPTER NOISE LEVEL MEASURED IN ICAO FLIGHT CONDITIONS APPROACH

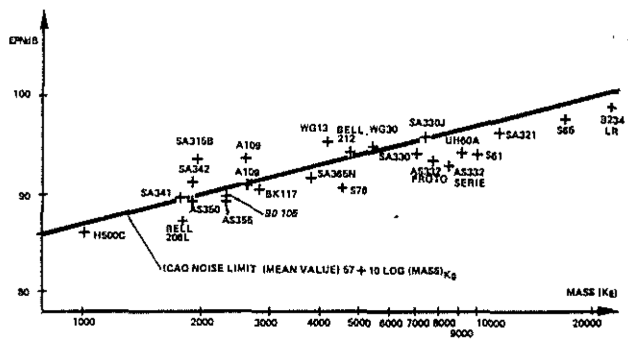

Fig. 11 : HELICOPTER NOISE LEVEL MEASURED IN ICAO FLIGHT CONDITIONS MEAN NOISE LEVEL

One can draw the following conclusions :

a) Eight different types meet ICAO's new-design requirements without trade-off.

b) Nine additional types comply with ICAO's new-design requirements when permissible trade-offs are applied.

c) Seven helicopter types do not comply with ICAO's new design requirements, six of these are within 3 dB above regulations. These are either old-design helicopters or versions derived from military design. Only one helicopter is of relatively recent civil design.

Since most recent civil helicopters are likely to obtain new-designs external noise certification, one might conclude that the standard defined for new helicopter designs is not too severe. Such conclusion might nevertheless seem hasty. Indeed, let us calculate for helicopters mentioned on fig. 11, the mean variations between mean measured noise levels and ICAO's mean noise limits. Such variation is + 1.5 EPNdB for helicopters above ICAO's mean noise limit and - 1.6 EPNdB for helicopters under ICAO's mean noise limit.
As the 90% confidence limit allowed for measurement is 1.5 EPNdB, one concludes that the probability to meet this requirement during certifications is not as high, even for recent technology helicopters, as it appears on figure 11.

The helicopter with the worst noise performance is the SA 315 B derived from the ALOUETTE II designed in 1960 : The mean of variations with respect to limits is 3.7 dB.
The helicopter with the best noise performance are the AS 332 and the S76 which recently obtained their certificate of airworthiness. Their mean of variations is equal to - 3.2. dB. The variation between the noisier old-design aircraft and the most recent helicopter is then 6.9 dB only. This rather low value evidences the impossibility for manufacturers to achieve spectacular noise reductions even if every helicopter was modified with the most recent technology.

2.6. REPRESENTATIVITY OF ICAO PROCEDURES

A standard is considered representative when the following three conditions are fulfilled.
a) The procedures applied must evidence noise generation phenomena particular to helicopters in normal operation.
b) These procedures must show the progress made after application of noise reduction technologies.
c) Noise measurements must correctly describe the nuisance felt by populations.

These three conditions are analyzed below

2.6.1 Do ICAO procedures really characterize helicopter noise sources during normal operations ?

The main acoustic phenomena characterizing helicopter noise are described below :

a) Flyover

At high flight speed, rotor blade tips being in the transsonic domain generate an impulsive noise perceived at very long distances. Noise levels measured increase rapidly with speed.

b) Descent

Interactions between blades and vortices occur within a very large descent rate/flight speed envelope and generate an impulsive, highly violent noise with maximum intensity under the helicopter and slightly forward.

Remark : Impulsivity is a specific character of helicopter noise in some flight phases. This specific character usually entails an increase in levels whatever the noise measuring unit is.

c) Climb

During climb at max. power, the highly loaded tail rotor and engines usually are main sources of external noise.

d) Maneuvers (bank, transitions etc....)

During maneuvers, similar blade/wake interactions, as described in Para. b) : Descent, also generate an impulsive noise.

The impulsive character of the noise radiated depends on the flight characteristics and, specifically, on the rate of climb or descent and on flight speed. Figure 12 extracted from BELL's paper entitled "How to Operate The Medium Range Helicopter More Quietly" presents the range at which two-blade helicopter noise is more or less impulsive in flight as a function of these two characteristic parameters. We have plotted, on fig. 12, the ICAO reference conditions applicable to a typical two-blade helicopter in order to show that impulsive noise character indeed appears, in ICAO stabilized flight conditions, in flyover and descent procedure.

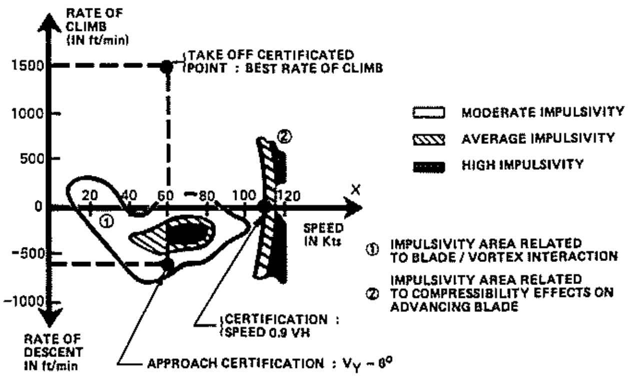

Fig. 12 : IMPULSIVE FLIGHT DOMAINS

While setting up ICAO draft, Working Group B could check from measurements taken at various flyover speeds or different descent slopes that impulsivity envelopes similar to those described by BELL also exist on other types of three, four.... blade helicopters.

One finds in most cases that :
- maximum noise during approach corresponds, on helicopters tested, to a 6 ° slope and a speed equal to VY.
- flyover at 0.9 VH speed corresponds to the high speed impulsivity domain.

Fig. 13 represents, in the altitude/speed diagrams, the safety envelope at sea level and maximum mass of an eight-ton helicopter, as specified in the Flight Manual. Evolution of altitude and speed during the three ICAO procedudes i.e. take-off, descent and flyover is shown in these diagrams.

One notices that:

a) Safety envelopes are observed in the three ICAO procedures

b) ICAO's take-off procedure is consistent with take-off procedure recommended in Flight Manual

c) ICAO's approach allows flying through critical point as specified in the helicopter's Flight Manual

Moreover, Working Group B checked during their work that 0.9 VH flyover speed is representative of the economic cruise speed generally applied by operators

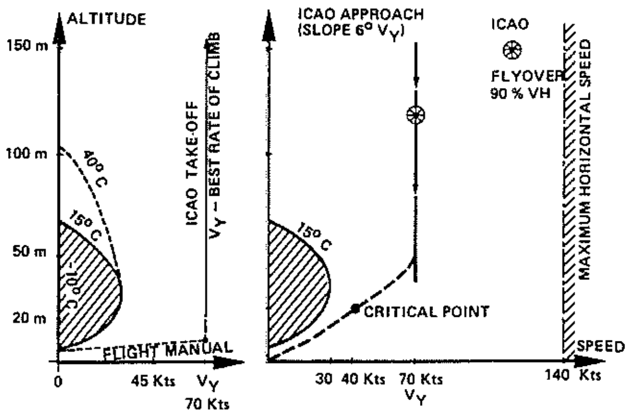

Fig. 13 : ICAO PROCEDURE VERSUS SECURITY DOMAIN

Conclusions of Para. 2.6.1.

Flight procedures as defined by ICAO are representative of main noise phenomena generated by helicopters. Levels measured represent maximum noise likely to be perceived by populations on ground during normal helicopter operation.

Note : From the examination of fig. 12 and 13, one notices that :

The impulsive character of helicopter noise can be reduced through use of procedures other than those specified by ICAO while observing the helicopter's safety envelopes. This aspect will be reexamined later in Chapter 3.

2.6.2. Does ICAO standard allow checking improvements obtained in the helicopter noise field ?

Figures 14 and 15 compare noise levels of helicopters of similar mass-category representing old designs and advanced-technology types.

Light helicopters, 2-ton category, are dealt with in fig. 14

A heavier, 7/8-ton helicopter category is dealt with in fig. 15

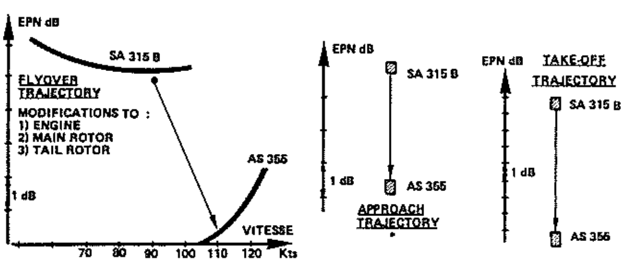

Fig. 14 : LIGHT HELICOPTER NOISE REDUCTION ACHIEVED

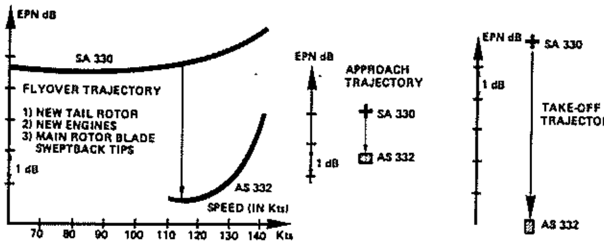

Fig. 15 : MEDIUM HELICOPTER NOISE REDUCTION ACHIEVED

These two examples evidence the advances made in noise research with the development of most recent technologies over the last 25 years.

Technical development is slow and there is, at present, no miracle solution similar to double flux engines on jet aircraft to reduce helicopter noise much further.

Conclusions of Para. 2.6.2.

The use of the ICAO standard permits to grasp the advances made in noise research.

Noise progresses achieved in the last 25 years are chiefly related to aerodynamics and performance improvements on rotor and engine. Additional gains in these fields may require quite a long time.

2.6.3. Does ICAO standard allow defining nuisance felt by populations upon normal helicopter operations ?

Working Group B selected EPNdB as a nuisance unit. This noise unit, currently used for large mass aircraft certification purposes, takes the frequency content of noise, the tone correction for pure tones and the duration of the perceived noise signal into account. This unit does not take into account any particular correction for the impulsive character of a noise signal.

Numerous psychoacoustic studies were undertaken in the last few years to quantify the amount of nuisance related to impulsivity. Several correction methods were suggested but, up to now, none was judged satisfactory enough to be retained by ICAO.

Indeed, comparison between juries' opinion on real helicopter noise and measurements processed either with new units taking impulsivity into account or with conventional units, demonstrated that EPNdB was statistically most representative of the nuisance related to helicopter noise. Among other units, those based on dBA, generally applied to quantify other types of urban noise, also present a rather appropriate correlation.

To compare the helicopter and other means of urban transportation for which noise is usually quantified in dBA max., we calculated, for helicopters, the difference between noise levels expressed in EPNdB and noise levels expressed in dBA max. Average values and standard deviations of these differences are presented on fig. 16 for the three flight procedures. From the above analysis, one can transpose ICAO noise limits from EPNdB into dBA max as shown on the same figure.

As illustrated, the three dBA max. limits are practically identical and can be expressed with a mathematical law as 45.4 + 10 log (mass)

EPN dB – dB A MAX.		ICAO NOISE LIMITS (dB A MAX.)
TRAJECTORIES		
FLYOVER	: 10.7 dB (σ=2 dB)	45.3 + 10 LOG MASS
TAKE-OFF	: 11.5 dB (σ=1.8 dB)	45.5 + 10 LOG MASS
APPROACH	: 19.6 dB (σ=1.5 dB)	45.4 + 10 LOG MASS
dB A MAX. LIMITS = EPN dB ICAO CONDITIONS-(EPN dB – dB A MAX.)		

Fig. 16 : RELATION BETWEEN NOISE LEVELS – ICAO CONDITIONS

The above law gives an average of 75 dBA for a 1,000 kg helicopter and 85 dBA for a 10,000 kg helicopter. Most urban operations are carried out with helicopters weighing between 1,000 and 10,000 kg.

Comparison between the above levels and those commonly measured for other noise sources (see fig. 17) shows that the noise perceived by an observer on ground upon passage of a 1,000 kg helicopter is equivalent to the noise perceived upon passage of a car. It also shows that upon passage of a 10,000 kg helicopter, the noise perceived would have been equivalent to that of a motor cycle running at high speed.

	dBA SOUND LEVEL AT 15.2 M	
ROCK DRILL	98	95 ← HELICOPTER 100 000 Kg
DUMP TRUCK	88	
MOTOR CYCLES (OFF ROAD)	85	
CONCRETE MIXER (TRUCK)	85	← HELICOPTER 10 000 Kg
PNEUMATIC TOOLS	85	
TRUCK OVER 4 500 Kg	84	
MOTOR CYCLES (HIGHWAY)	82	
AUTOMOBILES (SPORTS, COMPACT)	75	75 ← HELICOPTER 1 000 Kg
BUSES (CITY AND SCHOOL)	73	
TRUCKS (LIGHT, PICKUP)	72	
AUTOMOBILES PASSENGERS (39 FED. REG. 22297 - 1974)	69	

Fig. 17 : COMPARISON BETWEEN HELICOPTER AND OTHER SOURCES

There were less than 20,000 civil helicopters in the world (excluding eastern bloc countries) in 1980 and the best forecasts do not exceed 35,000 helicopters in 1990. (see fig. 1). Less than 30% of these helicopters will take up urban missions.

These figures are to be compared with millions of road vehicles as noisy as helicopters that are driven into towns every day.

Conclusions

The noise units selected by Working Group B do represent the nuisance felt by an observer. Use of simple and approximate laws relating noise levels expressed in EPNdB and noise levels expressed in dBA max., makes it possible to compare the helicopter noise level to those of other means of transport. Such comparison shows that the overall helicopter nuisance in an urban environment is considerably lower than that of other means of transportation.

2.7. CONCLUSIVE REMARKS CONCERNING ICAO STANDARD

Positive aspects and shortcomings of ICAO's standard can be summarized as follows:

a) Flight procedures

The procedures applied are representative of helicopter noise and maximum nuisance generated by helicopters in urban areas. These procedures allow quantifying advances made in the helicopter noise reduction field.

b) Economic aspects

Selection of ICAO standard has not yet been fully substantiated. Economic consequences of noise limits adopted here, in particular, have not yet been assessed.

Moreover, considering the facts that theoretical noise prediction models presently in use are poor and inaccurate and that, despite application of the best modern technologies, the noise level difference between quiet and noisy helicopters is small, one may conclude that the probability for a new helicopter to obtain acoustical certification is low.
Consequently, economic risks incurred by the industry being high, manufacturers may be induced to needless sacrifice of performance during design phase.

c) Environmental aspects

It can be said that the ICAO standard protects the environment from possible noise excess of new design helicopters and derived versions. Populations, however, are not guaranteed that the best designed helicopters shall not develop a nuisance due to multiplication of daily operations.

Such nuisance should not however be too high for urban populations since the best helicopters presently in service are not noisier than urban vehicles and since the number of helicopters operating in urban areas is very small compared to that of other vehicles.

Environment protection groups might criticize the ICAO standard in that it does not cover old-design, generally noisy, helicopters and does not limit the number of operations of any type of helicopter.

3. OPERATIONAL REGULATION

We have just seen that the ICAO standard is not sufficient for short term environmental protection.

Indeed, the development of noise reduction technologies will not permit spectacular, short term progresses and it will not be possible to apply such progresses immediately to the present fleet of helicopters

These helicopters will remain in service for a long time and will be employed in urban operations for many years.

Moreover, the nuisance associated with these helicopters increased somewhat during the last few years because of an increase in traffic.

This may explain why local organizations set up their own noise regulations; these regulations limit daily doses of noise imposed on populations and, consequently, force the operators to limit their daily number of operations.

In the first part of this chapter (See 3.1.), we shall give an example to illustrate the principles of these local regulations and their consequences for manufacturers and operators.

The multiplication of such regulations with their own criteria based on the sole protection of populations from helicopter noise could, in the long run, prove highly detrimental for the helicopter industry's future.

Helicopter Association, International (HAI) proposed that manufacturers, operators and crews develop a voluntary program to reduce sound level perceived on ground. Such noise reductions would be obtained by application of appropriate operational procedures to be determined.

This initiative could be interesting if :

a) Selection of procedures does not, as far as operators and manufacturers are concerned, have too large an impact on the operational cost effectiveness of a given helicopter, particularly, if they allow operating old-design helicopters.

b) The operational procedures applied effectively reduce nuisance imposed on populations.

c) In parallel to the efforts made by manufacturers and operators, local authorities will accept a compromise between nuisance levels imposed on populations, cost effectiveness imperatives of heliports and operators as well as direct or indirect benefits derived from helicopter operation by those same populations.

3.1. Example of an operational regulation

An example of operational regulation is given by the OFFICE FEDERAL SUISSE DE L'AVIATION CIVILE (OFA) in a document entitled "Directives pour mesurer et evaluer le bruit dans le voisinage des champs d'aviation pour helicoptères". The purpose of this regulation is to limit the number of operations around an heliport so that the hourly noise rate does not exceed a level acceptable to neighbouring populations (see fig. 18)

CLASSIFICATION OF NOISE SENSITIVENESS CATEGORIES I TO IV		LIMITATIONS	
SENSITIVITY DEGREE	BUILDINGS / AREAS EXPOSED TO NOISE	IN DB (A) SLOW	
		dB A MAX	Leq
I	– HOSPITALS, ETC ...	65	45
II	– BUILDINGS IN QUIET AREAS INTENDED MAINLY FOR DWELLING	75	55
III	– BUILDINGS BEATED IN DWELLING AREAS ALREADY EXPOSED TO NOISE	80	60
IV	BUILDINGS LOCATED IN INDUSTRIAL AREAS WHERE PEOPLE MAKE LONG STAYS	85	70
		HELICOPTER ONLY	

Fig. 18 : SWISS OPERATIONAL REGULATIONS

Four living areas were defined ranging from very quiet such as hospital areas to rather noisy such as industrial areas.

Noise measurements are expressed in dBA max. and LEQ (The level of a steady sound which in a time period, one hour in the case of OFA, and at a stated position has the same A-weighted sound energy as the time varying sound) . Helicopter operation will be prohibited in an area when noise level expressed in dBA max. is above limit. The number of operations is limited to one per hour when LEQ noise limit measured on building or at windows is equal to the noise limit set for this particular living area. Number of operations per hour for a given area exposed to noise will be equal to Antilog((LEQ OFA limit - Measured LEQ level)/10) when measured noise level expressed in dBA max. is below OFA limit.

Remarks concerning OFA's dBA max. limitations

From the noise measurement results obtained in ICAO's Working Group B framework and expressed in dBA max. units (See Para. 2.6.3.) for a mean 180 m distance between helicopters and observers, it has been possible to calculate, for each of the four areas defined by OFA, the maximum mass (see fig. 19, third column) of the helicopter whose dBA max. value is equal to the value imposed by OFA.

INHABITED AREAS	dB A MAX. LIMITS	MAXIMUM HELICOPTER MASS	
I HOSPITALS	65	90 Kg	23 Kg
II CENTER OF TOWNS	75	910 Kg	230 Kg
III SUBURBS	80	2880 Kg	725 Kg
IV INDUSTRIAL AREAS	85	9120 Kg	2300 Kg
		OACI DISTANCE (180 M APPROX.)	OACI DISTANCE / 2

Fig. 19 : OPERATIONAL LIMITS ON SWISS HELIPORTS

We note (see fig. 19) that the quietest living areas (Hospitals - town centers) are prohibited to helicopters weighing over one ton. The consequences of OFA's operational regulations are still more severe when helicopter/ observer distance is reduced (90 m - See fig. 19, fourth column); only industrial areas located away from urban centers will be accessible to light helicopters (under 2300 kg).

Remarks concerning OFA's LEQ limitations

The comparison between levels measured with old-design, noisy helicopters and new-design helicopters of same mass (see fig. 14 and 15) shows variations from 2 to 8 dB. The number of operations permitted per hour will be multiplied by a factor ranging from 1.6 to 6 with a quiet helicopter. Cost-effectiveness of the quiet helicopter shall then be enhanced as a higher number of operations is permitted per hour.

However, a regulation of the type adopted by OFA that would exaggeratedly limit the number of operations permitted daily will not allow the operators to be cost-effective even if they use the quietest helicopters in their fleet.

3.2. Possible noise reductions through use of adapted operational procedures

As shown in Para. 2.6.1., areas do exist over the helicopter's flight envelope where impulsive noise phenomena and measured noise levels are reduced.

a) Flyover

On some, generally recent, helicopters designed for high-speed flight, and at equal altitude and weight, limiting speed down to approximately 100/110 kts allows decreasing noise levels perceived on ground down to 6 EPNdB as compared to noise levels perceived at ICAO's flyover certification speed (0.9 VH). Although restrictions are imposed by airplanes' flight envelope, increasing altitude will also help reduce helicopter noise.

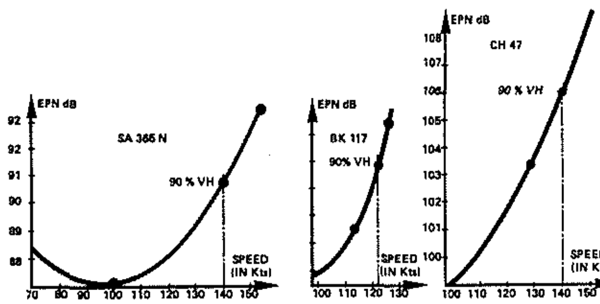

Fig. 20 : POSSIBLE NOISE REDUCTION IN FLYOVER

Comparisons already presented on figures 14 and 15 show that old-design helicopters considered noisy in ICAO standard will not really gain from flight speed reduction. The same probably applies to many old-design helicopters.
Definition of operational procedures should consequently widen the gap, already measured with ICAO procedures, between old-design, noisy and new design, quiet helicopters. The increase in the noise level gap between noisy and quiet helicopters may have an economic impact contrary to that desired by manufacturers and operators upon definition of operational procedures i.e. may, in the short run, lead to withdrawal of a good many old-design helicopters.

b) Take-off (see fig. 21)

Increasing the distance between observers on ground and helicopter trajectory seems to be the surest mean of reducing noise perceived. At a given pressure altitude and temperature, distance can be increased by decreasing take-off weight or speed over trajectory.

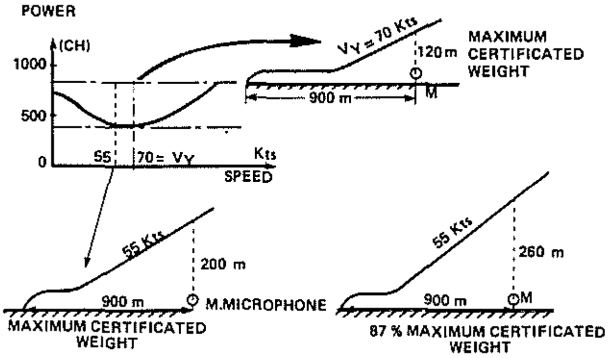

Fig. 21 : TAKE-OFF ABATEMENT FLIGHT TECHNIQUE

The first of these solutions may have undesirable consequences on operational cost effectiveness, the second solution may prove detrimental for safety by forcing pilots to work too close to limits of height/speed safety envelope.

In the example of Fig 21, noise reductions that might be obtained at observers standing 900 m away from the heliport and located under track or laterally (150 m to right or left) would amount to :

		TAKE-OFF SPEED	
		55kts	70 kts
reduction	MIKES UNDER TRACK	4.4 dB	
	LATERAL MIKES (150 m)	2.3 dB	

Similar procedures are applicable to every old or new design type of helicopter

Since performance and safety levels have been improved on new design, as compared to old-design, helicopters, research in new take-off operational procedures might be enhanced on such new helicopters.
Consequently, the acoustic improvements that will result from such research might lead, as in flyover, to rapid withdrawal of old-design helicopters.

c) Approach

To avoid acoustic phenomena related to blade/vortex interaction that may occur in descent phase, it would be necessary to fly around the speed/rate of descent envelope in which these phenomena occur.

An example of this flyaround procedure was proposed by BELL and is presented on fig. 22 (solid lines) in a speed/rate of descent diagram.

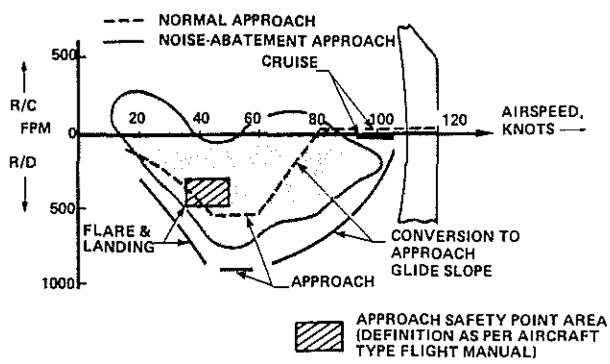

Fig. 22 : NOISE ABATEMENT FLIGHT TECHNIQUE

This diagram includes :

- Impulsivity envelopes
- Normal approach procedures (Dotted lines)

It is to be noted that :

* Normal approach must proceed through a safety point (Rate of descent/ Speed/Altitude) indicated in Flight Manual. This point is in general located in the impulsive envelope.

The flyaround procedure proposed by BELL avoids this point. Approach safety problem should then be studied again if such procedure were adopted.

* Moreover, this procedure including several phases with simultaneous variation of speed and rate of descent is rather complex.

* Finally, it is to be feared that noise generation in procedures with unstabilized flight parameters be different from that presented in BELL's diagram (see fig. 22) where flight parameters are stabilized.

Complete elimination of impulsive features in descent phase will permit gaining 4 to 5 EPNdB for an observer under track and 2 to 3 EPNdB laterally. Such gains will be difficult and will only apply to helicopters whose main noise source in descent is blade/vortex interaction, as is the case for helicopters classified as quiet in ICAO standard. On noisier helicopters, the relative importance of excess noise arising from such sources as engines or tail rotor may considerably reduce the efficiency of a flight procedure avoiding impulsivity envelope.

Conclusions

Rather high reductions of noise levels perceived on ground could be expected for some helicopters when flight conditions and appropriate trajectories are specially adapted. These reductions could be on the same order (5 to 6 dB) as those already obtained by application of the most recent technologies.

It is to be feared that the application of noise reduction procedures will favour operation of the quietest helicopters and lead to withdrawal of old, often noisy types equipping most of the present fleets.

3.3. Technical problems raised by definition of operational procedures and regulations.

a) There cannot be a universal procedure since every heliport and helicopter type is considered a particular case.

Particular access routes such as rivers and roads will impose specific maneuvers. Position of living areas i.e. of measuring points, direction of prevailing winds, heliport's altitude will also have an influence on the selection of trajectories.

Each type of helicopter has its own specific acoustic features; this applies mainly to old-design noisy types generating parasitic noise with particular directivities. The best noise reduction procedures will certainly not be identical for every helicopter type.

Noise reduction procedures shall be set up after long studies over a large number of helicopters and heliports.

b) The measuring unit applied by ICAO (EPNdB) is highly sophisticated and requires using a complex and costly equipment. As concerns operational procedures, it will be necessary to define a unit representative of nuisance imposed by helicopters. This unit should be easy to measure with a simple, universal equipment as the number of measuring points will be high while the levels will have to be permanently checked and compared with those of other urban nuisance.

c) As concerns limitations, we have seen in the example of Para. 3.1 that levels set too low might practically prevent operators from establishing regular lines on heliports in urban areas.

Consequently limitations should be set, as a function of the type of living areas, at an international, official level; to do this, a compromise is to be found between additional noise nuisance the inhabitants could tolerate, economic losses inherent to noise reduction procedures and incurred by operators and manufacturers and the social advantages of an heliport.

Only a neutral working group such as Working Group B of ICAO could define this compromise thus guaranteeing a fair regulation.

Application of local regulations should be deferred until conclusions of this working group have been published.

This working group should also specify how several operators could share work on a same civil heliport.

3.4. CONCLUSIVE REMARKS CONCERNING OPERATIONAL REGULATIONS

- Local regulations presently set up to decrease daily doses of helicopter noise imposed on populations are likely to be highly detrimental to the development of civil helicopter markets.

- Contrarily to ICAO certification standards which were defined in concertation by parties concerned and involved a large number of experimental studies, operational regulations are set up by local authorities, emerge mainly from a concern for reduced acoustic nuisance for the public and are directly enforced by the airport or heliport authorities.

The HAI proposal to form a large working group including manufacturers, pilots, operators, environment protection groups, local authorities and others to harmonize and synthetize operational procedure studies seems to be the best way to ensure, IN THE SHORT RUN, the development of helicopter operations in living areas.

While most of the work (Research in noise reduction procedures for each type of helicopter, definition of nuisance felt on ground with different calculation units, assessment of economic impact of noise reduction procedures for manufacturers and operators, impact of noise reduction procedures on safety of helicopter transport.....) could be performed by industrialists and operators in cooperation with local and national authorities, limitations should be set at an official, international level. It is the responsibility of manufacturing and operating states' authorities to form a working group similar to ICAO's group B in charge of limitations' definition.

As a consequence of the application of operational regulations, we can as from now predict the withdrawal of noisy helicopters from commercial operation in living areas since use of quiet helicopters only shall increase operators' cost effectiveness

4. GENERAL CONCLUSIONS : ICAO STANDARD AND/OR OPERATIONAL REGULATIONS ?

The characteristics of ICAO standard and operational regulations are recalled below :

	ICAO STANDARD	OPERATIONAL REGULATIONS
1 Procedures	1) have been defined 2) are representative - of max noise - of nuisance during normal operation 3) Allow quantifying noise reduction progresses	1) are not yet defined 2) will allow obtaining minimum noise 3) should be defined within HAI's frame-work
2 Noise Limitations	1) are defined for new design heli-copters 2) Proposals exist for derived ver-sions 3) No limitation for other helicopter categories 4) Economic impact of limitations adop-ted has not been fully analyzed.	1) Exist locally in various forms 2) Should be inter-nationally harmo-nized with a compro-mise to be defined between various parties concerned

3 Consequences for manufacturers and operators	1) No restrictions for old-design helicopters 2) Risk of a lowering in cost effectiveness for new designs and derived versions further to reduction in performance. 3) Long term research efforts to reduce noise generation at source.	1) Further to multiplication of local regulations : - Need to reduce number of operations in urban areas. - consequently, low cost effectiveness and withdrawal in time of helicopters from urban areas 2) Further to application of international regulation after compromise : - Development of urban traffic although old, noisy helicopters are withdrawn in time 3) Need for HAI to lead program defining operational procedures
4 Effects on environment	1) Continuation of operations with old, noisy helicopters for many years 2) Development of ever quieter prototypes and derived versions 3) No dose of noise concept related to number of daily operations	1) Operational regulations as they now stand : - Total protection of environment against helicopters 2) International regulation adopted after compromise : - Correct environment protection - Safety loss risks 3) Whathever their form, these regulations do not induce manufacturers to reduce noise generation at source.

To conclude, one can say that the compromise necessary between various interests of manufacturers, operators and populations shall be found :

- In the short run : by the implementation of operational regulations

- In the long run : by the application of standards such as that defined by ICAO.

ICAO standard and operational regulations are two additional tools that should induce a reduction in helicopter nuisance and the development of civil markets.