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A QUIET HELICOPTER
A RESEARCH PROGRAMME TODAY
A REALITY TOMORROW

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A QUIET HELICOPTER
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ABSTRACT:

This paper describes the extensive research undertaken or planned by EUROCOPTER, TURBOMECA and ONERA on the design of quieter helicopters to meet the changing regulations.

We wish to thank the French Government Agencies (DGAC, Services Techniques Hélicoptères, DRET, etc.) for their support on the quiet helicopter research programmes.

This paper has been broken down into two sections:

* The first section presents a review of the overall situation. It describes the considerable development possibilities for helicopter activities over inhabited areas and attempts to better assess the noise disturbance problem and evaluate the lines of actions that would enable the manufacturers to handle environmental issues. The three lines of action relate to:

  - a strategy for the development of small heliports compatible with their environment,

  - the introduction of minimum noise operational procedures,

  - future helicopter designs, which should feature lower operational noise levels. Our objective is to produce aircraft certified down to at least 8 dB less than the 1993 ICAO limits,

* The last section of this paper covers the research actions taken jointly by EUROCOPTER, TURBOMECA and ONERA and presents the results obtained on:

  - main rotors

  - fenestron type, fan-in-fin tail rotors,

  - engines.

All these results will be integrated into a single quiet helicopter demonstrator.

1. INTRODUCTION

In recent years, the commercial helicopter has proved to be an increasingly indispensable tool in a large number of activities. Thanks to its versatility, it can provide the most efficient and the most effective answer to community needs in a large number of situations arising in populated areas.

- It is the fastest solution for search & rescue operations (accidents, fires), police operations, assistance missions, flights, etc. over short and medium ranges.
- It is the only vehicle capable of quick and direct access to certain areas (e.g. office building roofs) as it circumvents the increasing number of traffic jams and slow-downs in conventional transportation systems.
- It is the sole vehicle capable of performing certain types of work as it avoids the location of highly disturbing work site installations for the community, etc.

Another advantage compared to other transportation systems is that the helicopter operates with limited infrastructures, e.g. its "terminal" merely consists of a grass pad.

Notwithstanding these advantages, helicopters are subject to strong opposition from the environmental protection organisations.

This may seem rather surprising, if we consider today that:

- The commercial helicopter fleets are extremely small, even in the best equipped countries; a recent statistical study shows that France has about 12 commercial helicopters per million inhabitants and furthermore that they only operate partially over populated areas;
- Compared to other types of transportation, helicopters only generate an infinitesimal part of the global noise; in fact, helicopter activities in populated areas could be considerably developed to meet the current needs without this global noise component becoming significant (an AS 350 flying over at 300 meters at cruise speed generates no more noise than a passing car or powerful motorcycle in the street).

Unfortunately, helicopter operations are concentrated at a small number of heliports, thereby creating noise "overdoses" around these heliports as well protests from the nearby residents and a deluge of operating regulations that sometimes drastically curb helicopter activities.

We feel that, provided the noise problem is suitably handled, helicopter operations can be developed in populated areas in the joint interests of the manufacturers, the operators and the community.

There are three possible lines of action to meet this challenge.

2 LINES OF ACTION

<u>1st line of action</u>:

In urban planning, helicopter operations must no longer be treated in the same way as conventional aircraft (i.e. by concentrating operations in a well-defined heliport) but, on the contrary, spread out over a large number of helipads close to the sites of potential customers.

Moreover, the layout of these future heliports must be planned to cater for the noise problem and for the ground noise footprints of all types of commercial helicopters.

The area of heliports should be minimised by locating them adjacent to industrial, commercial or other activity centres already classified as noisy areas and by making them accessible from the outside via feeders or by-passes such as waterways, highways, motorways, railways, sea links, etc. (see Figure 1).

City planning around heliports must be regulated. In fact, experience has shown that it is not enough to cut down helicopter noise and to reduce helicopter operations in existing heliports but it is also necessary to protect their environment by classifying them as "disturbance zones", as has been done for the major airports.

Without such a statute, chaotic city planning may mean that all the research to design quieter helicopters in the future will be rendered null and void.

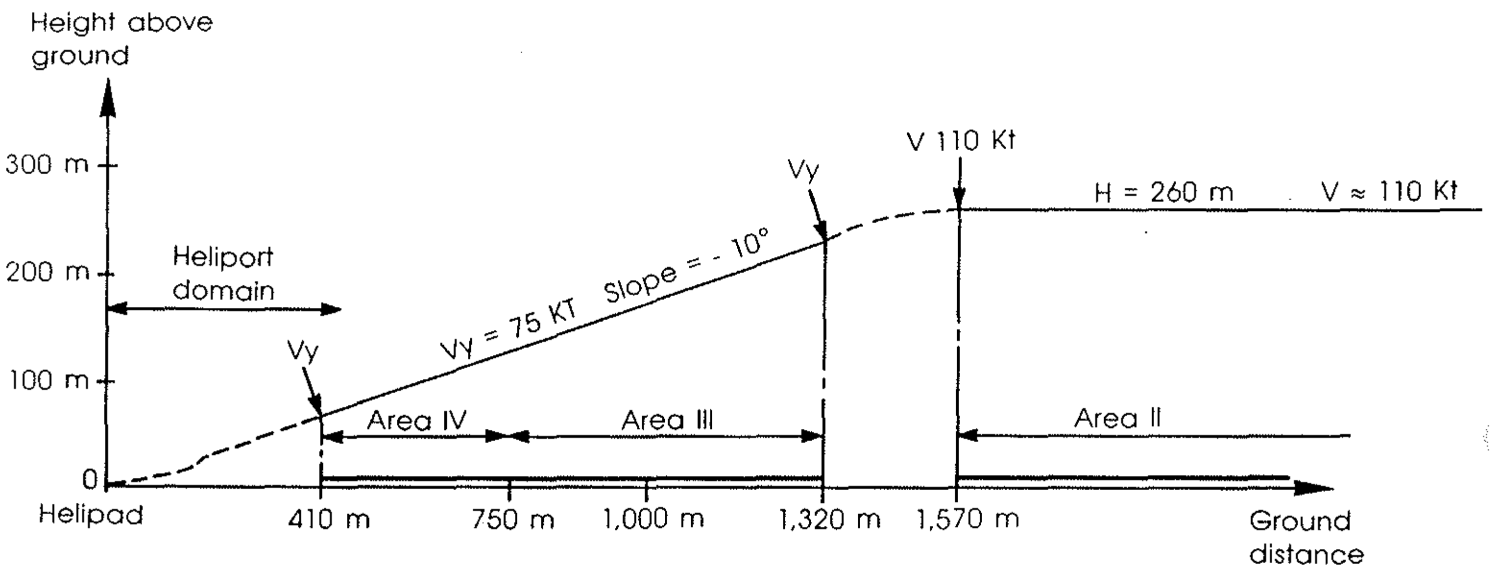
2nd line of action:- Helicopter Operators and Pilots

The helicopter's outstanding manoeuvring capability must be utilised to optimise helipad approaches and take-offs by minimising the most aggressive noise (e.g. the characteristic blade slap of helicopters) and by keeping the flight path as far away as possible from noise-critical areas.

This type of low noise procedure can be applied to all existing helicopters to obtain immediate noise benefits but it should also be integrated in the design of future quiet helicopters.

The success of this action implies both pilot training in these noise abatement techniques and strict observance of their application in operations over populated zones.

Figure 1 indicates that, for a medium-sized helicopter, the ground distance between the touchdown point and the various noise-critical areas (in accordance with Swiss Air Federal Office's regulations) decreases with increasingly steep descents.



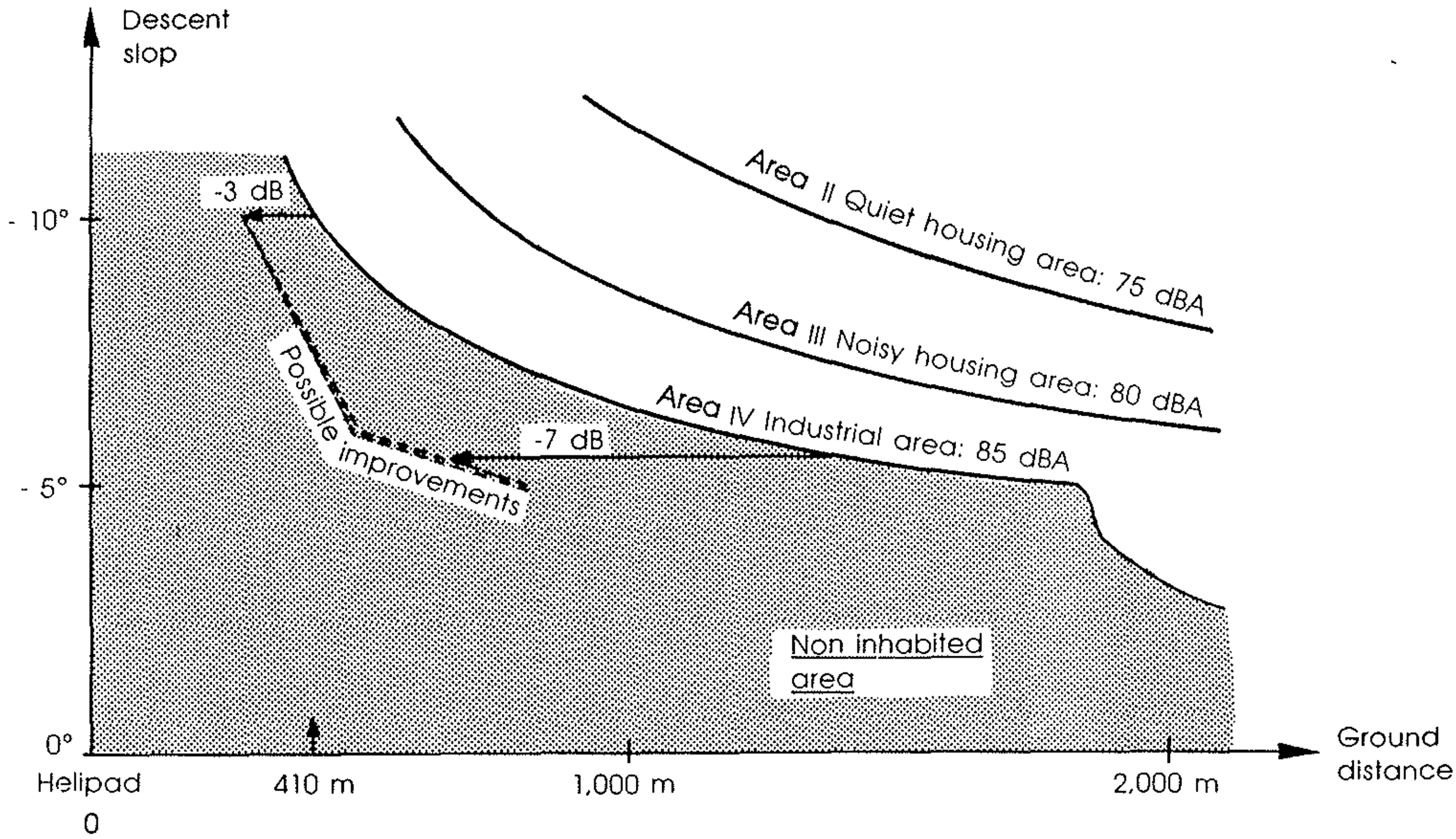


FIGURE 1 - LANDING PROCEDURE IN COMPLIANCE WITH ENVIRONMENT NOISE PROTECTION

However, the research conducted in recent years on descent-generated noise has shown that the expected noise reductions at average slopes of 6° are greater than the potential gains at steep slopes (10°). Since each procedure (low slope, high slope) may offer operational advantages according to the heliport sites selected, quiet helicopter designers must attempt to obtain maximum reductions in slap noise at average slopes while *preserving a reduced noise landing capability at steep slopes.*

<u>3rd line of action</u>:

For several decades now in co-operation with a number of research centres and with official assistance, we have been pursuing research programs aimed at understanding the multiple noise sources in helicopters and at controlling them right from the design stage.

The quiet helicopter programme (whose main features will be described below) answers the need to conquer the helicopter market in populated areas while remaining acceptable from an environmental standpoint.

The assigned objective is to produce a helicopter whose certification noise level (as per the ICAO procedure - ICAO Appendix 16, Chapter 8 - the only internationally recognised procedure) will be at least 8 EPNdB less than the CAEP1 limits (see Figure 2).

Meeting this objective should offer real improvements in helicopter noise but it entails a considerable research effort to solve the design problems and at the same time to satisfy the performance and profitability criteria.

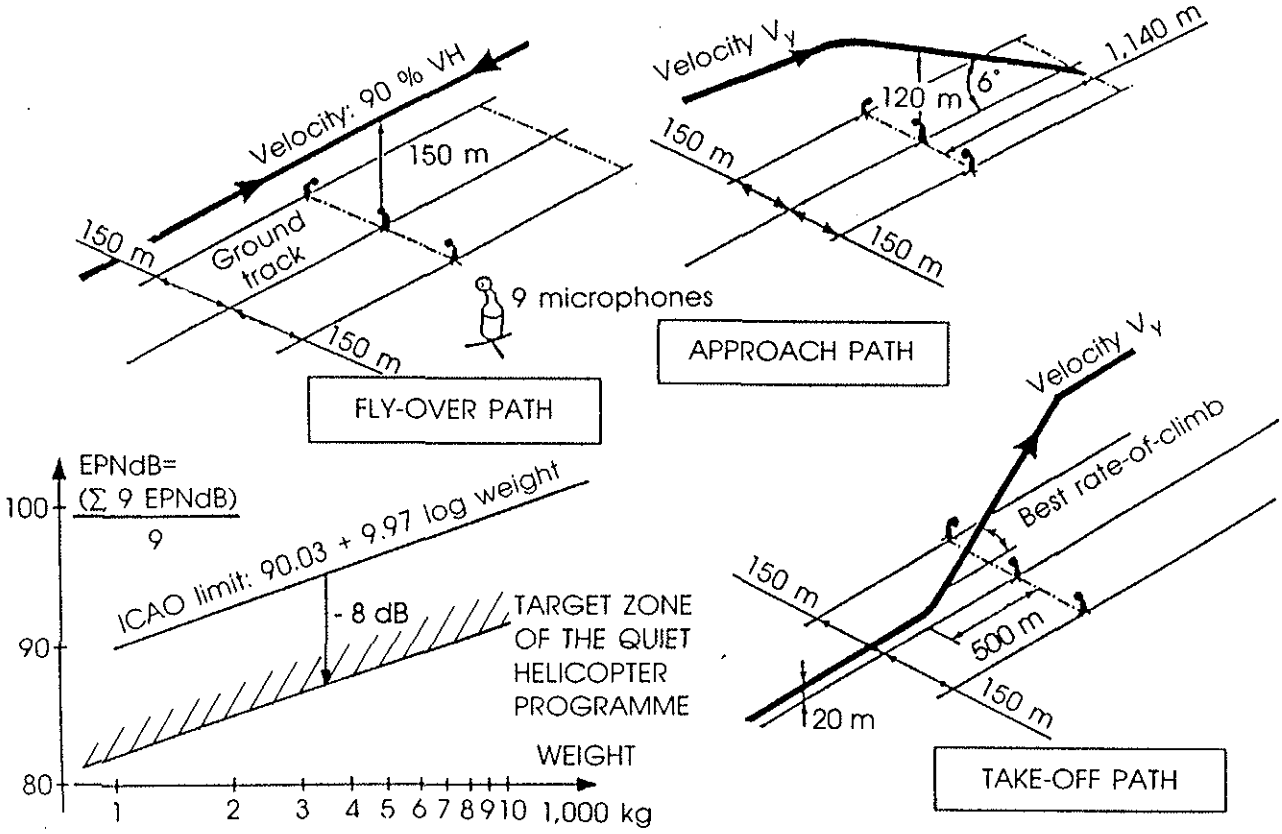


FIGURE 2 - QUIET HELICOPTER PROGRAMME OBJECTIVE DEFINITION - IN ICAO CERTIFICATION CONDITIONS

3. PROBLEMS TO BE SOLVED

3.1 What is helicopter noise made of? Major lines of action

Helicopters involve a set of extremely complex noise sources generated by the main and tail rotors as well as the engine(s) (see Figure 3). Experimental data from a large number of helicopters indicate that not only does the relative importance of each noise source vary but that the type of noise generated by each source also varies with the flight conditions (take-off, fly-over, approach, bank, hover, etc.).

Main rotor: impulsive noises

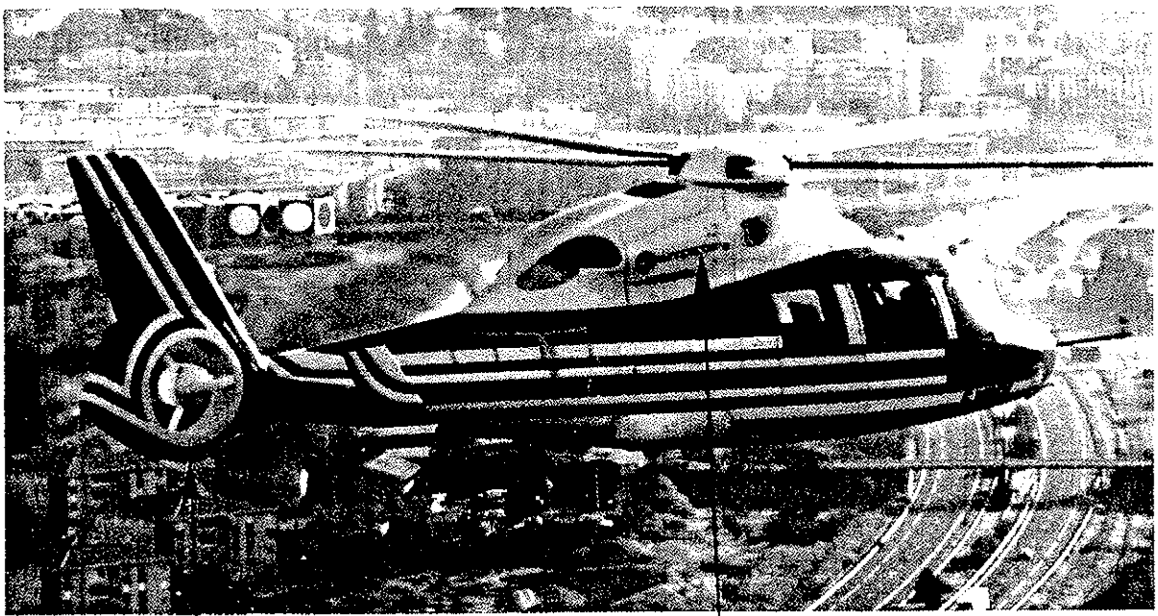
Pure sounds 20 Hz => 1,000 Hz
Broadband noise

Loads: Lift, Drag

Advancing blade compressibility effects

Blade/wake interactions

unsteady flows



TAIL ROTOR

a) Pure sounds
Classical: Low frequencies
Fan-in-fin: Medium frequencies

b) Broadband noise
Type of noise:
- Thrust loads
- Interactions with structure
- Main rotor wake
- Stator vanes

ENGINES

a) Pure sounds: 10 KHz

b) Broadband noise
Sources:
Compressor
Turbines
Combustion
Nozzles

FIGURE 3 - NOISE SOURCES ON A HELICOPTER

Thus in the quiet helicopter programme with the target of -8 EPNdB below the certification limits, priority has been placed on reducing the sources of helicopter-specific noise, i.e.:

Main rotor impulsive noise (Figure 4):

- due to interactions between blades and vortices in descent flight;
- due to compressibility effects in high speed forward flight.

Pure sound noises in hover, take-off and fly-over:

- from the tail rotor (Figure 5);
- from the engine compressors;

The aim is to obtain a residual noise source with as high a broadband noise specificity as possible. Such a broadband noise will tend to blend into the environmental noise of cities and be no different from the noise of a passing car in quieter neighbourhoods.

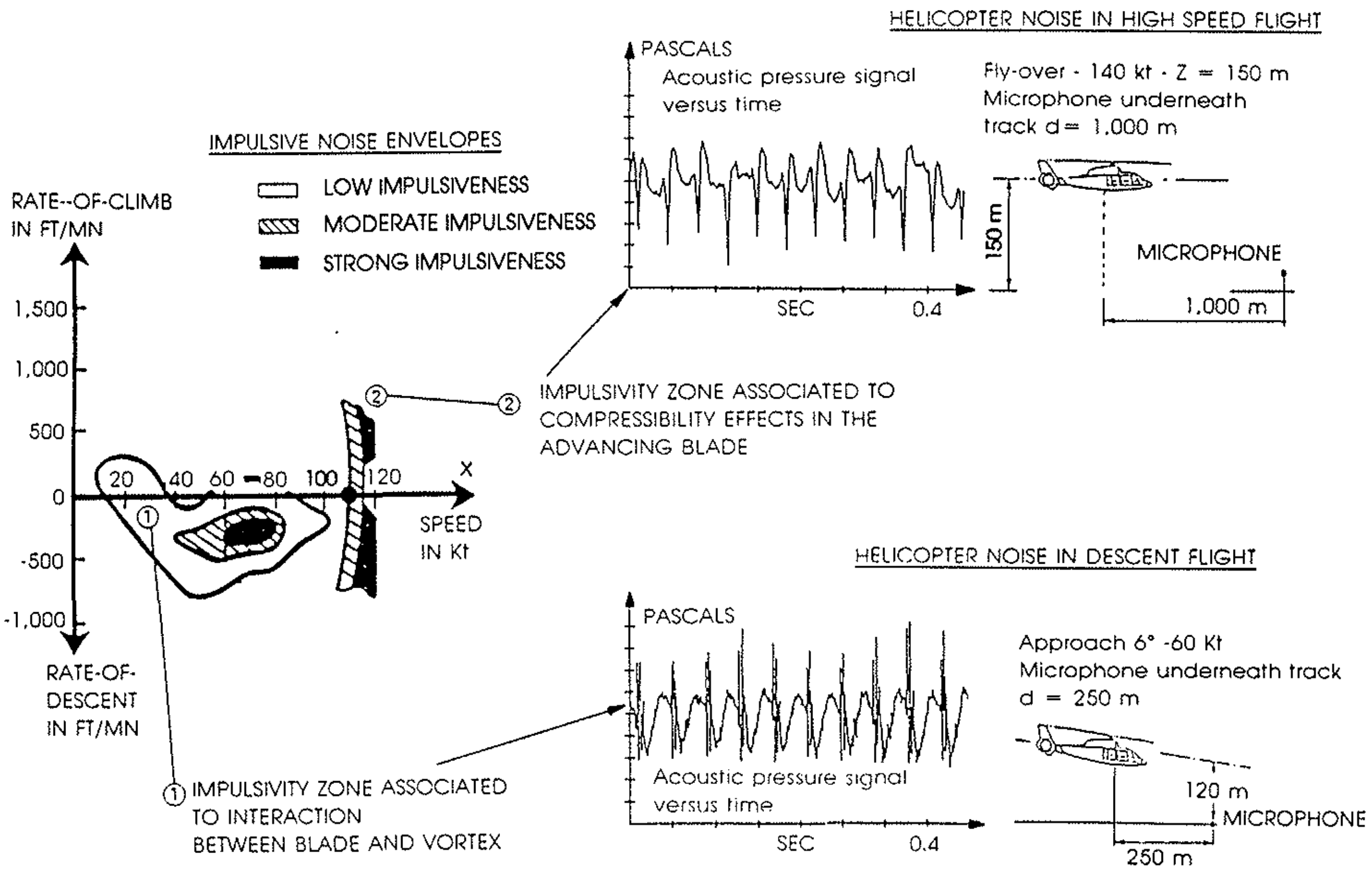


FIGURE 4 - IMPULSIVE FEATURES OF MAIN ROTOR NOISE

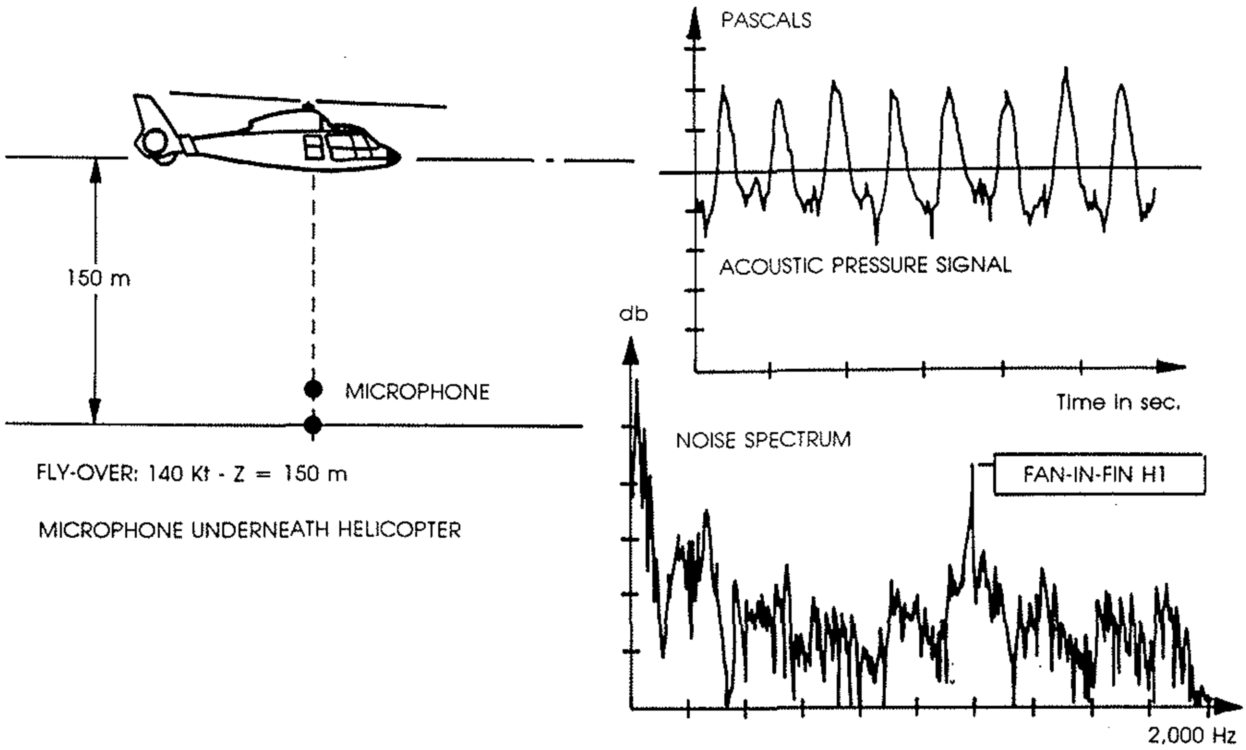


FIGURE 5 - FAN-IN-FIN PURE SOUND GENERATION IN HIGH SPEED FORWARD FLIGHT

Reducing the emitted sound power and neutralising the specific features of rotor and engine noise will not be feasible without accepting a number of constraints affecting not only the acoustic design but also the other performance, cost and safety criteria.

3.2. Constraints associated with quiet helicopter design

a) <u>On global helicopter design</u>:

Helicopter design has always been a trade-off between hover and forward flight performance, flying characteristics, safety margins in case of engine failure, the lowest possible vibration levels, etc. in the context of minimum weight, minimum purchasing and operating costs and maximum reliability. The acoustic component therefore introduces additional constraints in each flight phase.

Helicopter manufacturers will therefore have to make new trade-offs and master the capability of reducing noise levels in operations over inhabited areas while retaining the aircraft's ability to meet the needs of a large number of other operators - all the more so because many operations are performed in areas of low noise sensitiveness where excessive performance, purchasing and operating cost penalties would not be acceptable.

b) On acoustic design

The dominant aeroacoustic phenomena in the various flight phases are totally different and they will not all necessarily be best resolved with the same solutions. Trade-offs should help obtain a similar residual disturbance in each flight phase. There is no point in taking off quietly if the landing is noisy.

The noise reduction efforts must therefore be applied equally to all the noise sources for a given flight configuration.

The example in Figure 6 indicates that the maximum disturbances (in terms of Noy in accordance with ICAO Appendix 16) for priority noise reduction are the main rotor in take-off and landing, and the tail rotor in take-off and fly-over. Flying with variable rotor rpm can considerably reduce the noisiness of the main rotor in fly-over phases and of the tail rotor in all flight phases.

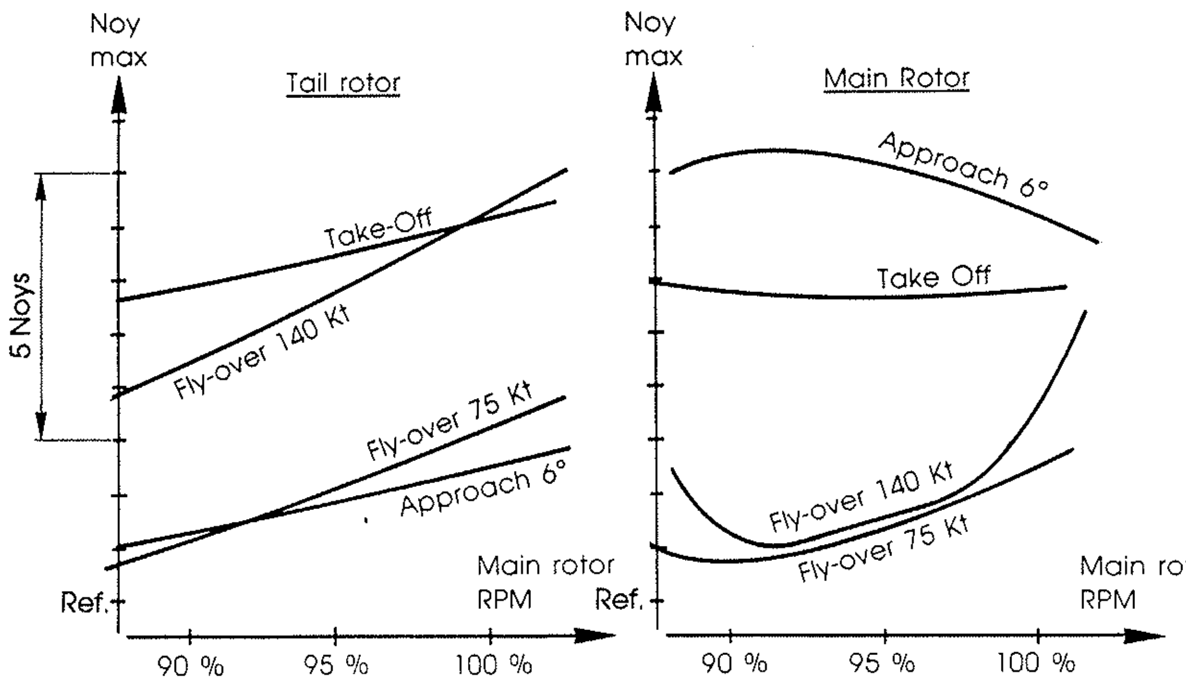


FIGURE 6 - RELATIVE MAIN AND TAIL ROTOR NOISINESS DEPENDING ON FLIGHT CONFIGURATIONS AND ROTOR RPMs

c) <u>Modifiable parameters</u>

The efforts underway for many years to understand, model and reduce helicopter noise have identified many design parameters that could be modified to control noise generation:

- e.g. <u>for rotors</u>, blade tip shape, planform geometry, twist, airfoils, mean line, diameter, blade chord, rotor rpm, flight controls, disk loading, (choices for Cx allowing either low or high Vy), rotor/structure interactions, etc.

  Thus the design of a quiet helicopter requires a knowhow of all the aeroacoustic fields of each noise source.

  The aim of our research work in recent years (described in § 4 below) has been to acquire this knowhow. The quiet helicopter demonstrator programme will therefore have to integrate all these results and determine the optimum trade-off.

Of all the parameters available, one - the tip rotor speed - is of particular interest. The table below lists the results from two versions of the same helicopter with practically equivalent performance levels. The first version has a 4-blade main rotor with a tip speed of 225 m/s whereas the second features a 5-blade main rotor (practically the same blades) with a tip speed of 200 m/s. Apart from the 12.5% reduction in rpm, no improvements were made to the tail rotor nor to the engines.

The noise levels measured in ICAO acoustic certification conditions have the following margins with respect to ICAO limits:

	4-blade main rotor version U = 225 m/s (at	5-blade main rotor version same weight) U = 200 m/s
Fly-over (0.45VH + 65KT) = 132 Kt	-4.2 EPNdB	-7.5 EPNdB
Take-off Vy = 75 Kt	-3.1 EPNdB	-6.1 EPNdB
6° approach Vy = 75 Kt	-1.2 EPNdB	-4.6 EPNdB
Average	-2.8 EPNdB	-6.1 EPNdB

(i.e. a difference of 3.3 dB)

However, this solution is costly as, for the same performance and the same mission, it entails an all-up weight increase of approximately 6 % and a power increase of approximately 8.6 %, which pushes up the absolute noise level by roughly 0.3 dB, i.e. the real noise reduction between the two versions is 3 dB.

Thus to lessen the effects of a fixed reduction in rotor rpm, the current trend is to consider varying the rotor speed in a way which would produce noise benefits at lower tip speeds in the vicinity of inhabited areas while providing full performance and manoeuvrability outside these areas (see Figure 7).

This will only be possible with the use of high efficiency, free turbine engines whose rotary part design and variable speed control have been fully developed to guarantee the necessary operating dependability (adequate surge margins, etc.) without any negative effects on engine-generated noise. This variable speed engine design is the subject of a joint Turbomeca/Eurocopter research programme supplementing the quiet engine programme for a quiet helicopter.

It should be noted that the noise benefits from variable rpm can only be realised within the framework of ICAO type certification when such rpm reductions become mandatory for the certification test conditions (Zp = 0 ft - θ = 25°C - Max. all-up weight and V = Vy or V = 0.9 VH).

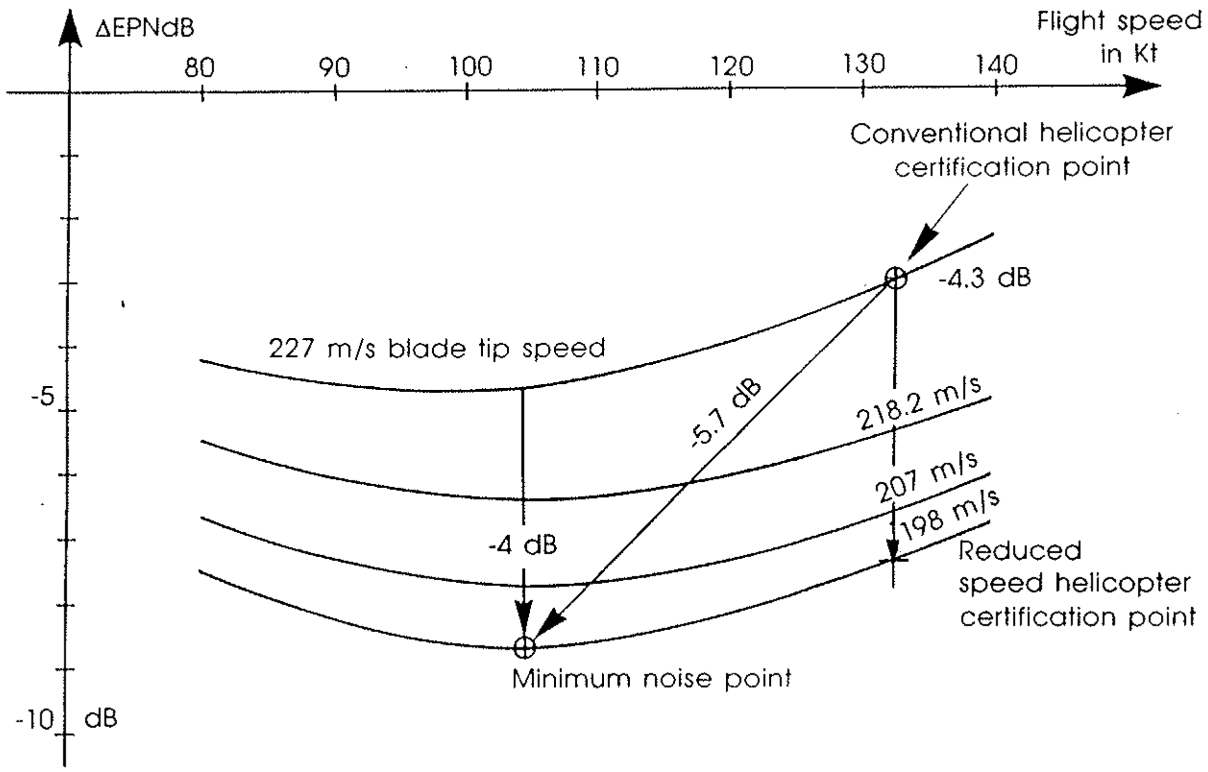


FIGURE 7 - INFLUENCE OF FLIGHT SPEED AND BLADE TIP SPEED ON NOISE LEVELS IN FLY-OVER PHASES (DEVIATION FROM THE ICAO LIMIT)

3.3 POSSIBLE OPERATIONAL ACTIONS

Operational capabilities and possible enhancements in the most disturbing phase i.e. landing have already been dealt with in Chapter 1 discussing those actions that need to be extended to improve the helicopter.

Consequently, this chapter only discusses the constant altitude flight phase which takes the helicopter close to the heliport after flight over large inhabited areas.

Operationally, the nuisance felt on the ground can be reduced:

a) by flying as high as possible

However, helicopters are often imposed a low ceiling because of the need to share airspace with aircraft or as a limitation due to clouds. As a result of low ceiling increases, acoustic gains will thus be limited under track and almost zero sideways (1000 m).

Furthermore, a horizontal flight phase at higher altitude will impose a longer descent with a higher noise penalty close to the heliport.

b) by multiplying flight axes to the heliport

This will help reduce the number of flights per hour on each axis, while increasing the total number of take-offs and landings on the heliport.

However, the constraints generated upon take-off and landing into the wind, which is usually dominant along 1 axis, shall limit the efficiency of this procedure.

c) finally, one can attempt to determine, as shown in the example below with a medium category helicopter, the flight speed conditions with minimum noise. This example also shows the operational acoustic efficiency of a reduction in rotor rotation speed (in addition to blade shape and engine design optimisation).

The most stringent operational regulations currently in force restrict helicopter flights on the basis of two criteria:

The first criterion is based on the maximum noise during fly-over, expressed in max. dBA level. It controls the access of the helicopter to various types of noise-critical areas, ranging from the quietest zones (e.g. hospitals) to the noisiest (e.g. industrial areas) and including noisy or quiet residential areas. It should be noted that this type of regulation penalises large helicopters since, as a first approximation, the noise level increases by at least 3 dB for a two-fold increase in weight.

The second criterion is based on the noise dose generated in each helicopter fly-over. It is expressed in LEQ_{1hour} and is used to determine the maximum possible number of fly-overs according to the total amount of noise allowed in each type of the areas mentioned above.

Based on these two criteria, Figures 8 and 9 illustrate the variations in noise level underneath the track in the fly-over phase for an existing helicopter, then those for the same helicopter but with rotor blade tip speed reduced from 227 m/s to 198 m/s, and, finally, the levels which would be obtained with an additional 3 dB noise reduction by acoustic optimisation of the rotors and engines.

Figure 8 demonstrates that for the existing helicopter to fly over noise-critical inhabited areas, its speed must be no more than 130 Kt. With a 3 dB drop in the noise due to a 13 % lower rotor blade tip speed, the number of flights per hour in a noise-critical housing area (Figure 9) could be doubled.

An additional 3 dB from rotor and engine design improvements would also allow this helicopter to enter quiet housing areas a considerable number of times, i.e. 10 flights/hour with a speed limitation of 120 kt.

The analysis of the fly-over case confirms the operational benefits of this two-way noise reduction approach, i.e. by using an optimum fly-over speed in operation and by decreasing noise through lower rpm and optimisation of the rotor and engine design.

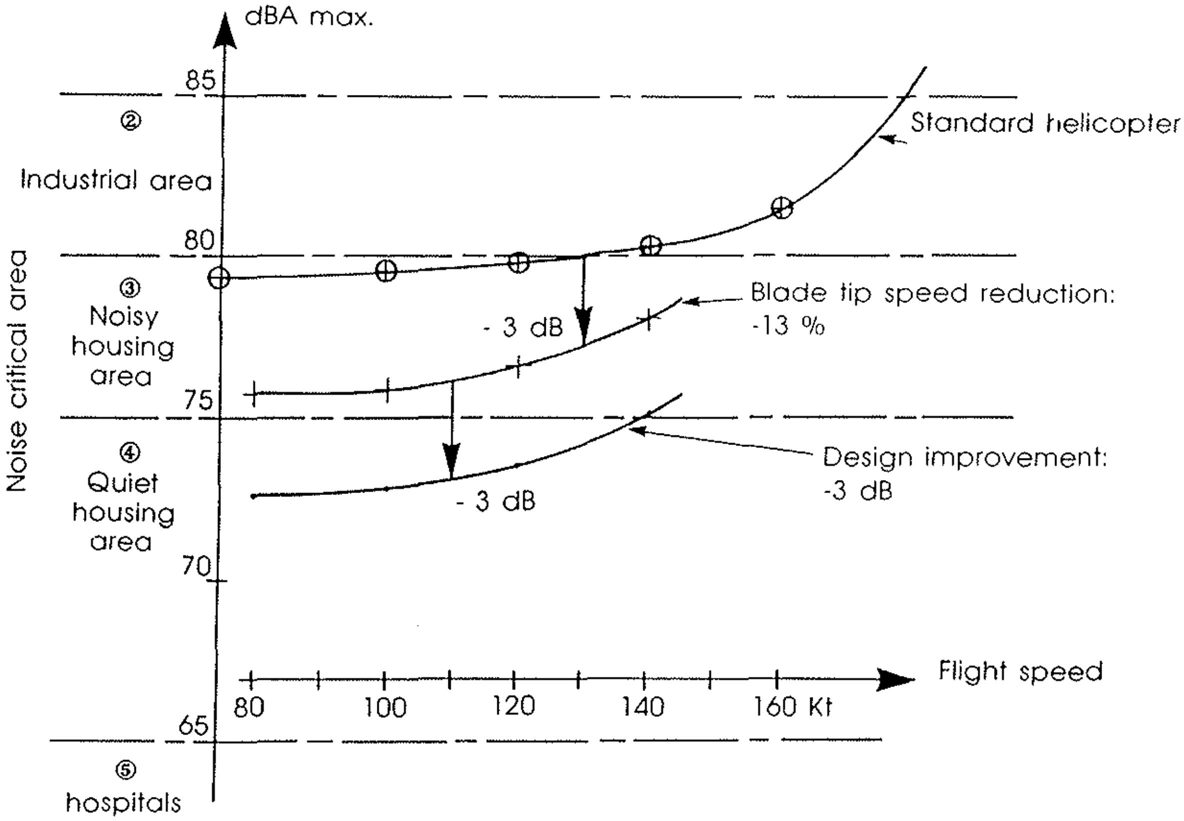


FIGURE 8 - MAX. NOISE CRITERION

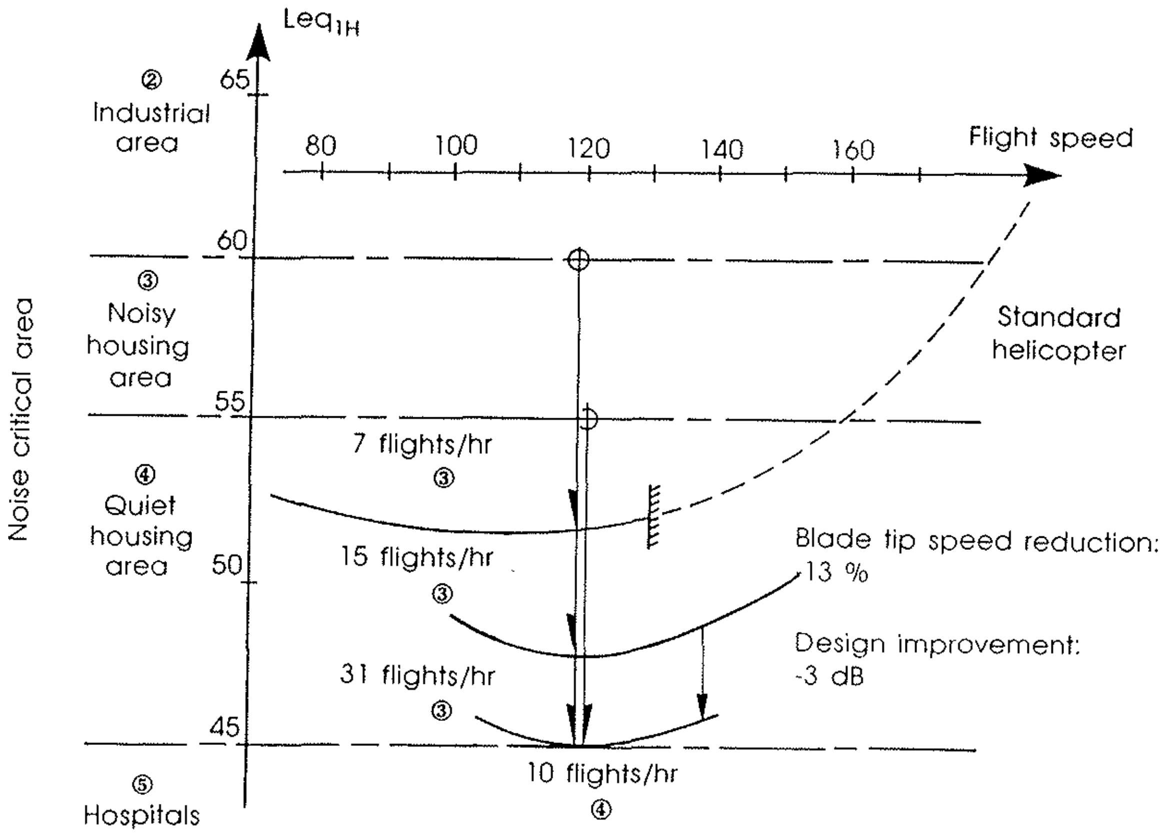


FIGURE 9 - NOISE DOSE CRITERION: NUMBER OF FLIGHTS/HOUR

4. RESEARCH IN FRANCE

To meet the quiet helicopter challenge and solve the problems posed, it is necessary to conduct tailored research work on the main and tail rotors as well as the engines.

4.1. Research work on the main rotor

An extended research study called ERATO ("Etude d'un Rotor Aéroacoustique Technologiquement Optimisé", Study of a Technologically Optimised Aeroacoustic Rotor) was initiated under a Franco-German co-operation programme including the ONERA and DLR research centres as well as the EUROCOPTER FRANCE and EUROCOPTER DEUTSCHLAND industries. The purpose was to define, build and test in a wind tunnel, a "quiet" rotor featuring no power and vibration penalty against the best currently available rotors.
The main objective was to reduce a reference rotor noise level by at least 6 dBA, in 3 characteristic flight conditions (descent in accordance with the ICAO procedure and level flight at high speed and minimum noise speed).

N.B. In the take-off phase, this work was mainly on the tail rotor and the engines.

The work plan mainly involved:

- the development of the necessary prediction codes;
- parametric studies including both conventional geometry blades and advanced geometry blades;
- the definition of an optimum rotor;
- the manufacturing and testing of this rotor in the ONERA Modane S1 and the DNW wind tunnels in the Netherlands.

4.3.1. Code development at EUROCOPTER and ONERA

- A rotor free wake code (MESIR code), enabling proper prediction of the relative positions of the blades and vortices whose interaction with the blades generates penalising noises in the approach phase; this code is coupled to a post-processor allowing the roll-up of the vortex sheet to be modelled (MENTHE code)
- A code for pressures on blades, when the vortex comes into near-collision with the blades (ARHIS code).
- An acoustic code (PARIS) enabling the rotor's acoustic signature to be calculated in those configurations (see Figure 10).

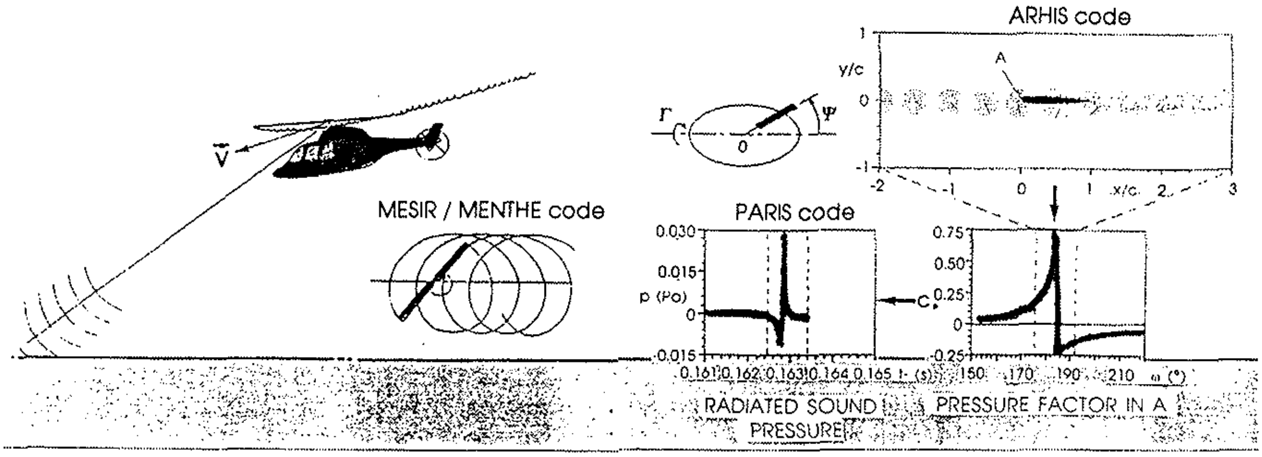


FIGURE 10 - BLADE/VORTEX INTERACTION NOISE PREDICTION

Figure 11 shows that these codes provide quieter accurate predictions of the acoustic signature for a conventional 2-blade rotor tested in the DNW wind tunnel.

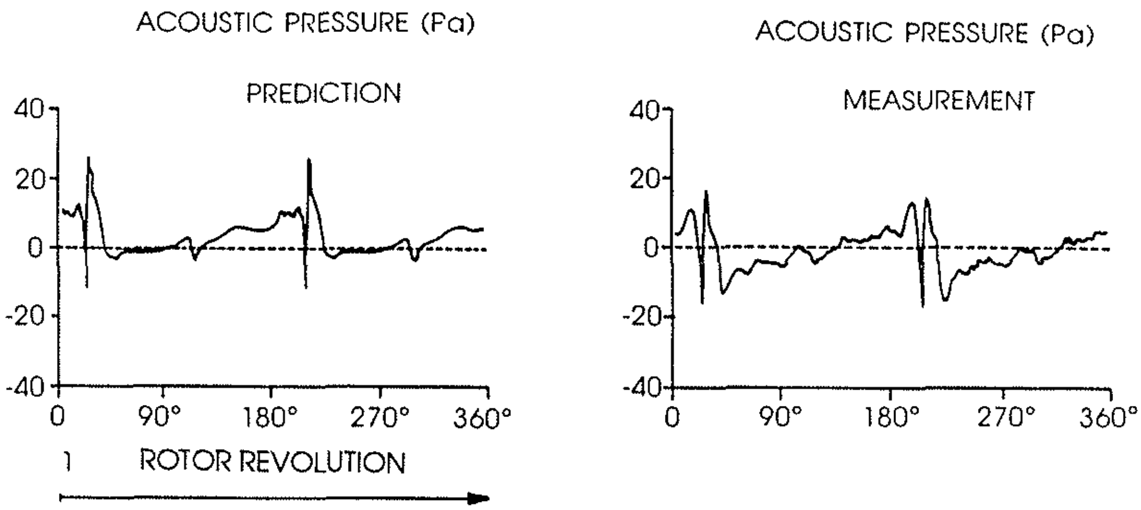


FIGURE 11 - CALCULATION/EXPERIENCE COMPARISONS FOR THE AH1G-OLS ROTOR (2-blade rotor)

Figure 12 shows that the shape and level of the measured and computed noise contour plots underneath the rotor are quite similar for a 4-blade rotor model tested in the DNW wind tunnel. The same prediction quality is also found in comparisons of rotors controlled by a higher harmonic control system.

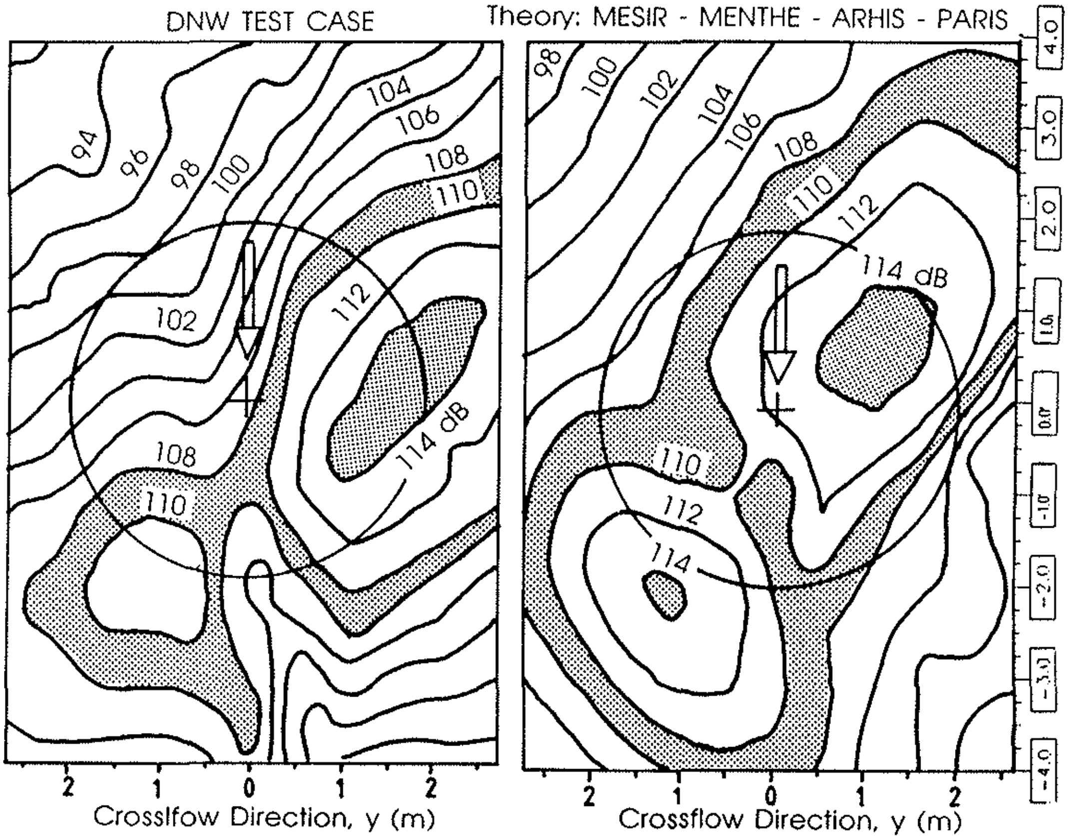


FIGURE 12 - CORRELATION WITH 4-BLADE ROTOR TEST RESULTS IN DNW WIND TUNNEL

These codes were also used to predict the effect of blade tip speed on the blade/Vortex interaction noise.

Figure 13 shows, for example, the noise contour plots calculated with a conventional blade tip speed of 210 m/s and the corresponding values with tip speeds reduced to 185 m/s and blade chord increased by 20 % to obtain the same lift capacity.

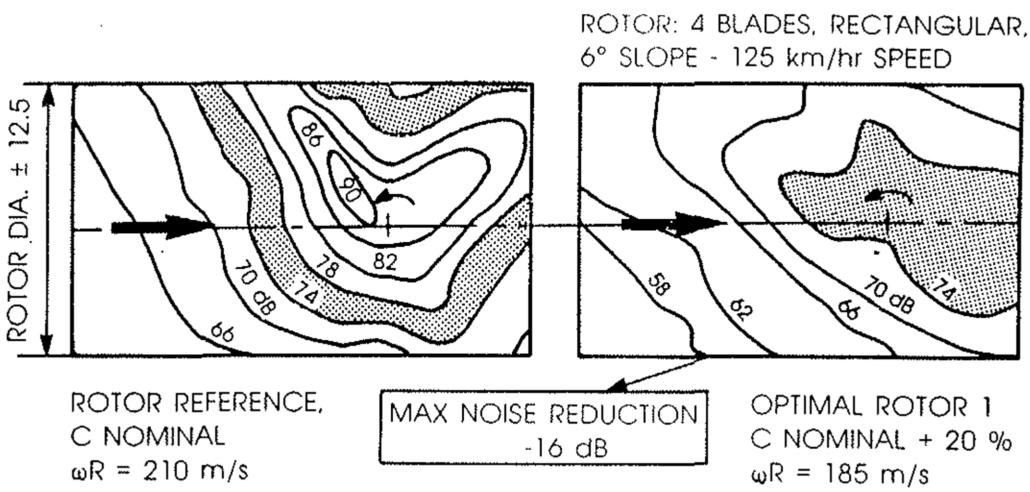


FIGURE 13 - BLADE/VORTEX INTERACTION NOISE CONTOUR PLOTS

The acoustic gains for this type of noise are very high (16 dBA) in this case, but the tip speed reduction is excessive and incompatible with the other criteria, i.e. performance, weights and costs (refer to first part).

Therefore, the objective of the ERATO research work being conducted is to define new blade shapes (non rectangular planform, non linear twisting, advanced blade tips and new airfoils) generating less noise while enabling smaller reductions in tip speeds to be adopted.

4.1.2 Blade tip studies

a) **Figure 14 shows examples of efficient blade shapes that help reduce Blade/Vortex Interaction noise in descent flight.** The acoustic results were recorded in the CEPRA 19 wind tunnel of CEPr at Saclay, France. Acoustic gains of up to 9 dBA are possible.

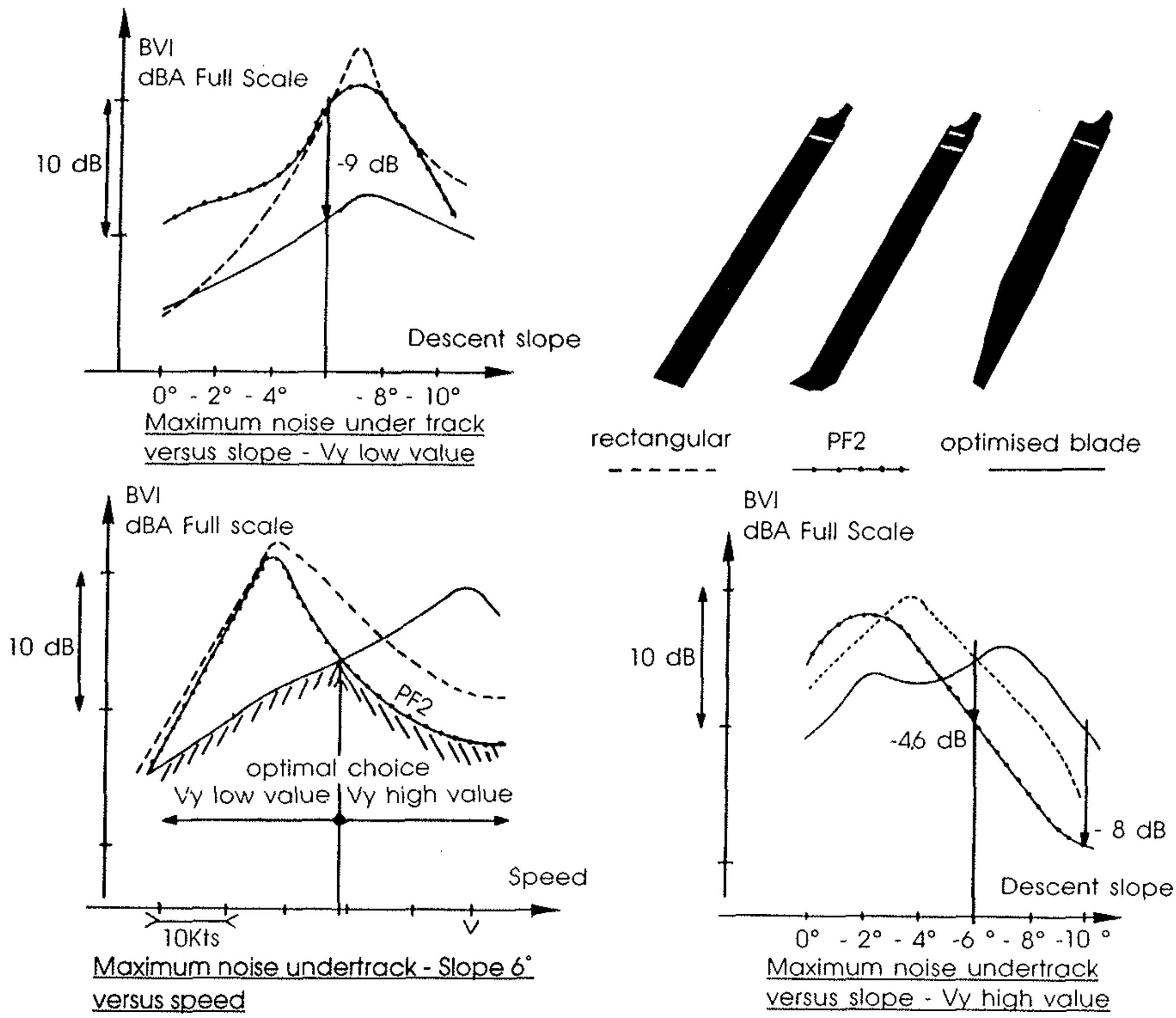


FIGURE 14 - BLADE TIP EFFECTS ON BLADE/VORTEX INTERACTION NOISE REDUCTION

However, these significant acoustic gains are accompanied by some drawbacks, i.e. the swept parabolic tip end (PF2) generates high blade control loads in flight, and the non linear twisting tapered blade causes power penalties in fast forward flight.

b) **An example of efficient blade tip noise reduction in high speed flight is given in Figure 15.**

When the advancing blade's Mach No increases, the impulsive component of the noise becomes extremely violent, the strength of the shock waves increases and the noise propagates easily when the shocks reach the sonic line (shock delocalisation phenomenon). As shown in Figure 15, it is possible to reduce the shock strength and delay the delocalisation phenomenon by optimising the blade tip shapes, and subsequently, obtain highly significant helicopter noise reductions for the same blade tip Mach No.

ISOMACH LINE CALCULATION:
SHOCK DELOCALISATION AT HIGH MACH

HELICOPTER NOISE MEASUREMENT
WITH BOTH BLADE TIP SHAPES

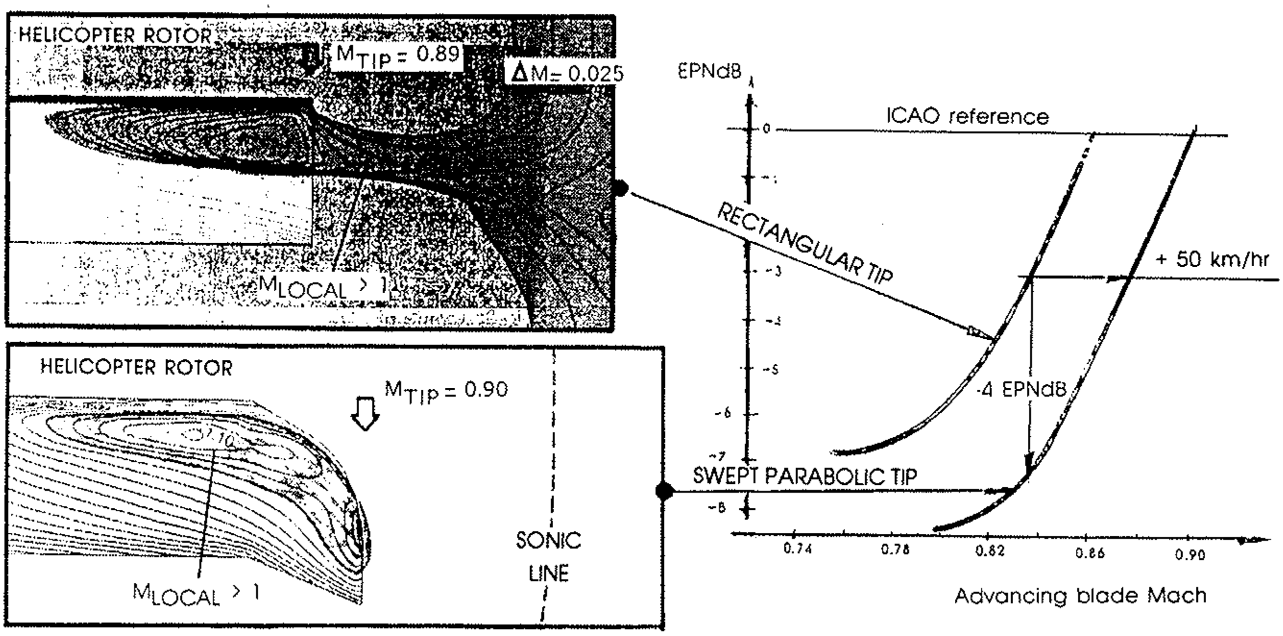


FIGURE 15 - HIGH SPEED NOISE - INFLUENCE OF BLADE TIP SHAPES

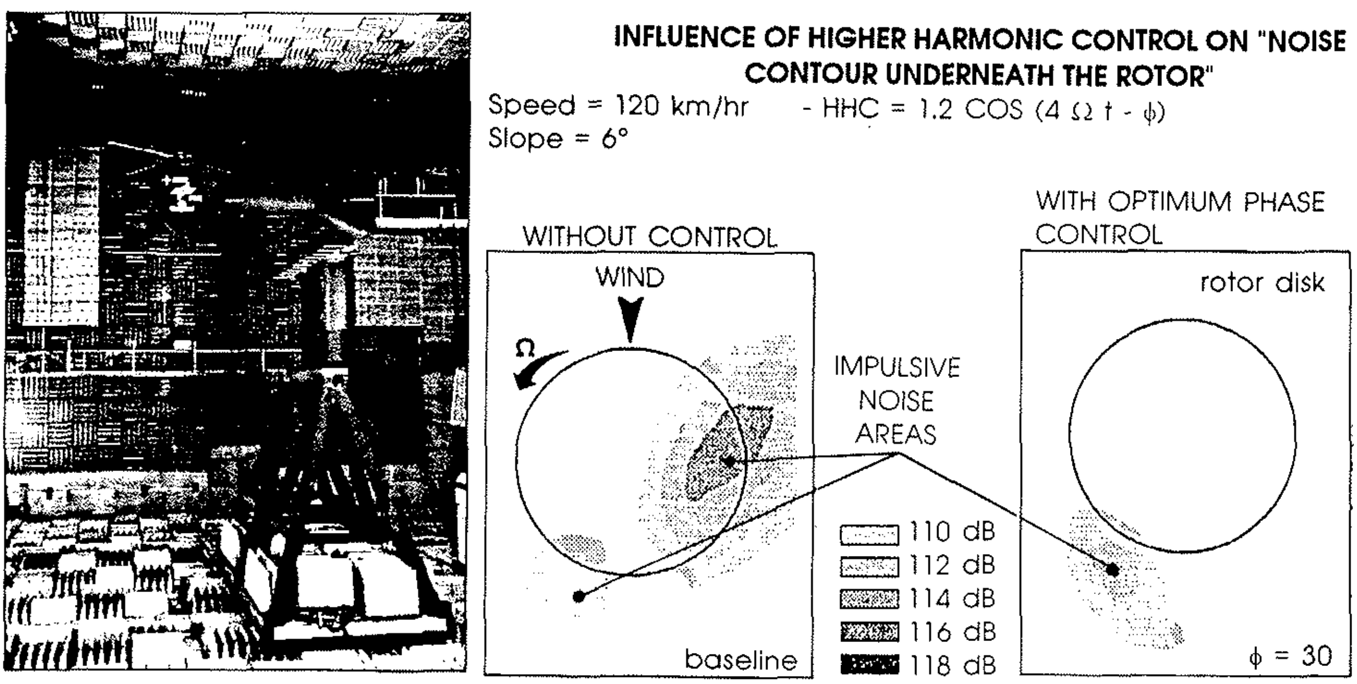
It is thus necessary for the ERATO study to design an optimised aero-acoustic blade which minimises possible penalties throughout the flight envelope. This blade can be used in conventional monocyclic control but it will be checked to see whether it can be further improved by the use of higher harmonic control.

4.1.3 Higher harmonic rotor control

This technique has proved effective in reducing blade/vortex interaction noise on conventional rotors. It has been successfully tested on rotor models in the DNW wind tunnel (see Figure 16) and by Eurocopter in experimental research trials with Gazelle helicopters .

In the case illustrated (Figure 16), the conventional monocyclic control law is compared with a 4/rev. control law (for a 4-blade rotor), with a suitable phase to reduce tip vortex intensity in the advancing blade area and to minimise its interaction with the following blade.

Despite the outstanding research results obtained, the normal helicopter operating conditions involving various aerodynamic speed instabilities will require to refine self-adaptive algorithms.



DNW WIND TUNNEL

FIGURE 16 - IMPULSIVE NOISE REDUCTION IN DESCENT FLIGHT

4.2. Research work on shrouded tail rotor: the quiet fan-in-fin

EUROCOPTER FRANCE has made special efforts to make the fan-in-fin tail rotor quieter. The early models generated high intensity pure sounds from 1,000 to 3,000 Hz, which is consequently unpleasant for the human ear.

The main objective of the quiet fan-in-fin research programme was to eliminate this pure sound effect.

- First, all the "spurious" aero-acoustic phenomena such as interactions between rotor and stator were reduced.

- Then, the acoustic effects of reducing the blade tip speed by down to 40% were evaluated with respect to the first generation of fan-in-fin rotors. The objective was to reduce noise generation and operate at lower frequencies, hence causing less disturbance to the human ear. Gains in excess of 6 dB were achieved.

On a quiet medium-sized helicopter in the 4-6 metric ton class, such rotor speed reductions are not easy to implement; in fact, to perform the same anti-torque function at reduced speed, not only must the size of the fan-in-fin be increased proportionally with the weight, but also the higher resulting drag must be compensated by increasing the main rotor power. Furthermore these two phenomena are amplified by the effects of reducing the rpm of the main rotor to reduce its own noise.

To "cancel" the effects of the residual pure sound resulting from blade tip speed reductions compatible with the helicopter's architecture, the rotor design incorporates a modulated blade arrangement.

Figure 17 illustrates the fan-in-fin with phase modulation tested by ECF on the hover rig at Marignane, and in the CEPRA 19 anechoic wind tunnel of CEPr at Saclay. Comparisons of the noise spectra of modulated and non modulated fan-in-fin rotors clearly demonstrate that the noise level at the natural bΩ frequency (as well as its multiples) is significantly attenuated at a given blade tip speed. Though the global sound energy remains practically unchanged, its distribution is different with the strong contributions at the natural frequencies eliminated (corresponding to the number of rotor blades b and its multiples and Ω the rotor shaft rpm). It should be noted that these design features have already been integrated in the helicopters currently being developed (EC 120 and EC 135) and have demonstrated their efficiency in flights of the EC 135 prototypes.

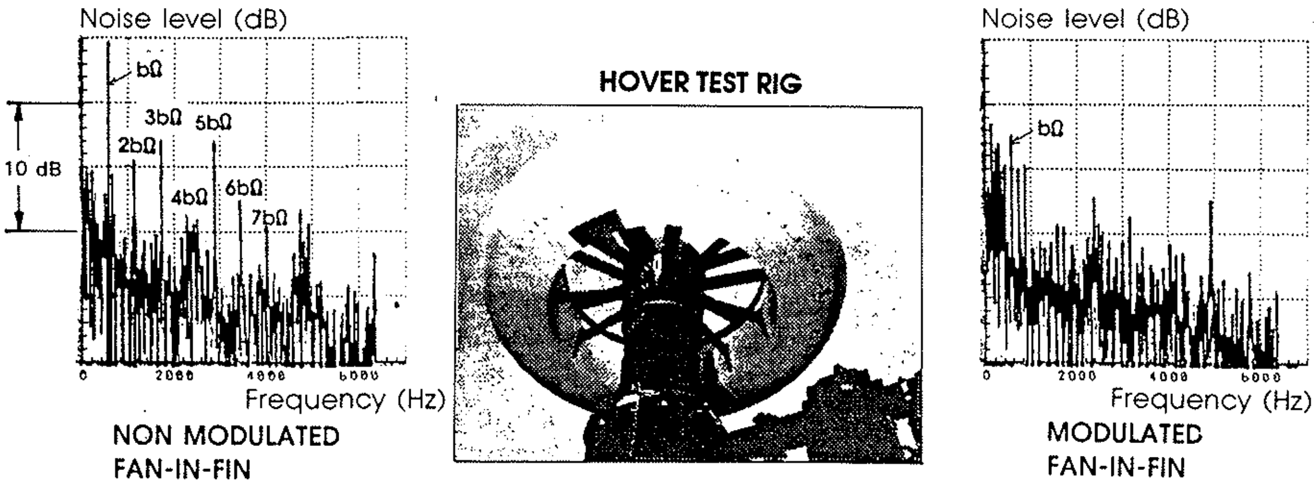


FIGURE 17 - QUIET FAN-IN-FIN

4.3 Research work on engines

Even though Turbomeca's present day turboshaft engines are appreciably less noisy than those of the first generation (gains in the order of 10 to 15 dB), they remain a major source of noise in the take-off phase of current helicopters (see Figure 18).

This is why the objectives of a research programme currently underway at TURBOMECA, ECF and ONERA are to:

- sound-proof the engine air intakes and nozzles efficiently,
- substantially reduce the compressor and internal noise.

The objective is a reduction such that the engine would become a secondary noise source compared to the main rotor in all flight configurations, with, in particular, the compressor noise (pure sound) diminished by up to 10 dB.

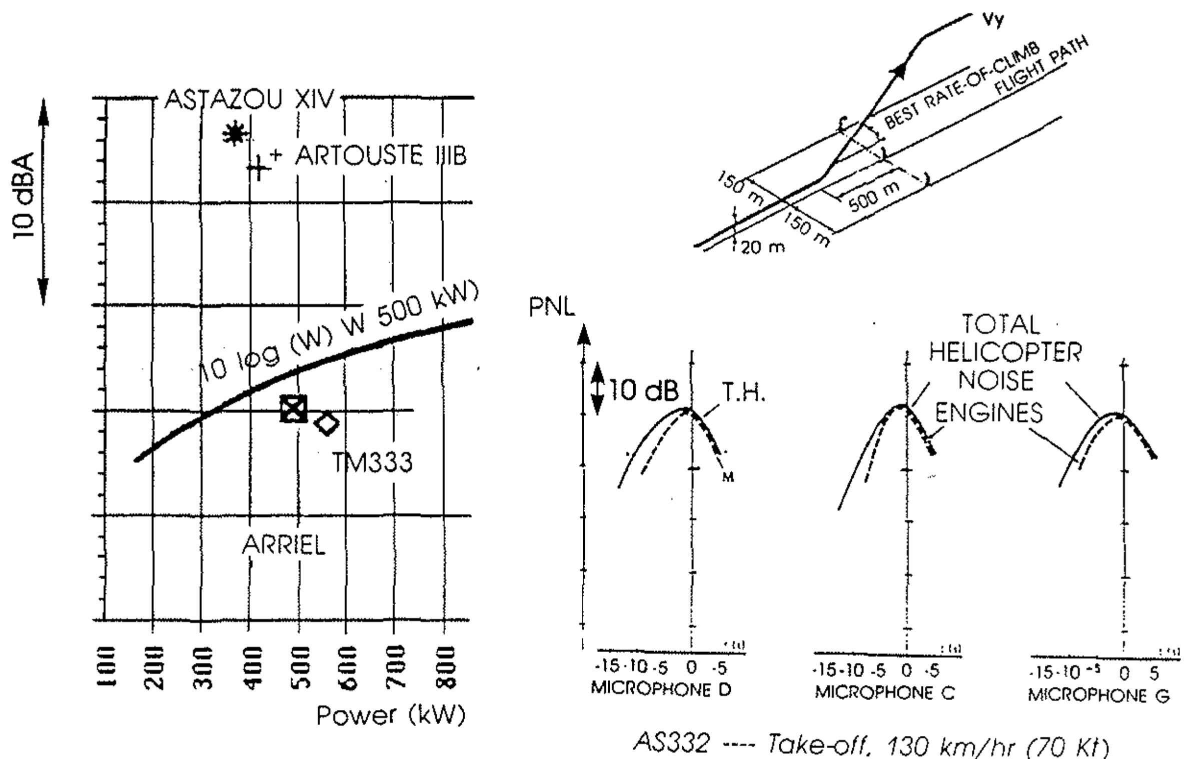


FIGURE 18 - ENGINE CONTRIBUTION TO HELICOPTER NOISE

4.4 The "quiet helicopter" demonstrator programme

EUROCOPTER has implemented an ambitious quiet helicopter flight demonstrator programme, whose final objective is to demonstrate the feasibility of reducing the external noise of future generation helicopters in the 4/6 metric-ton class by at least 8 dB versus the current ICAO standards.

The basic helicopter selected for this programme is the EUROCOPTER High Speed Dauphin and the following tasks are planned:

- evaluation of noise reduction new technologies for the main / tail rotors and the engines after the research work mentioned above;

- evaluating the external noise reduction achieved overall by cumulating options on the various sources in the three flight configurations (take-off, approach, fly-over);

- evaluating penalties possibly introduced by new concepts, and in particular, a reduction the rotor blade tip speed, entailing recommendations for the definition of an economically feasible quiet helicopter;

- evaluating new operational procedures for low noise flights

It should be noted that the trade-off required between helicopter noise and performance levels throughout the flight envelope dictates the implementation of active engine control devices, on which research is also being conducted.

5. CONCLUSION

Noise reduction is the key factor in the development of helicopter operation over inhabited areas;

Noise research programmes have been undertaken for a number of years now with full conscience of this fact.

A large part of the research work undertaken in France on the understanding of aeroacoustic phenomena and the analysis of new concepts has already been applied to the helicopters being developed by EUROCOPTER (EC120, EC 135).

Beyond this stage the Quiet Helicopter demonstration programme will provide the necessary data so that the next generation helicopters are truly QUIET in the environmental sense of the word.

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