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HELICOPTER TURBOSHAFT ENGINE ACOUSTIC AND INFRARED STUDIES AND TESTS

by

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ACOUSTIC AND INFRARED STUDIES AND TESTS

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ABSTRACT

The following statement concerns the field of the acoustic and infrared detection of helicopter turboshaft engines. After having recalled the necessity of these studies, test facilities in use and main research being carried out at present at TURBOMECA, are described.
Finally, a few significant results in the acoustic signature reduction are shown.

1. INTRODUCTION

Among the sensitive area concerning helicopter turboshaft engines, one has a specific position, due to its relatively recent appearance in the history of turboshaft engines ; this area concerns the acoustic and infrared detection (or discretion).

It is an area with which the engine manufacturer is preoccupied, in the same manner as performance, reliability, or the cost of an engine, but the contour is more uncertain and the target to be reached depends upon many factors and therefore becomes unprecise.

The following statement will permit, I hope, to give a better appreciation of the real stake which is proposed to the turboshaft engine manufacturers with respect to discretion.

2. NECESSITY OF ACOUSTICS AND INFRARED STUDIES OF A TURBOSHAFT ENGINE

2.1 ACOUSTIC DESIGN IN THE CIVIL FIELD

In the case of the acoustic detectability, we are exclusively preoccupied by the civil application of the helicopter.

It is certain that the helicopter causes inconvenience for people living beside heliports or for the people being in its trajectory. This inconvenience, more or less important as per the size of the aircraft and according to the number of flights for a given time, has progressively brought the authorities of various countries and the local responsible persons to find an answer to defend the persons concerned.

The International Civil Aviation Organisation has issued regulations defining the limited noise levels corresponding to the usual operating conditions of the helicopter : take-off, landing and flyover.

Certain countries have also issued their own regulations.

Finally, mainly in the USA, certain states have often fixed very severe noise levels, which directly limit helicopter flight numbers during a given time.

Naturally, the turboshaft engine is not the only one unit responsible for helicopter noise. TURBOMECA studies carried out with AEROSPATIALE, show that engine noise is negligible for the landing phase, of the same order of magnitude as the rotor noise levels, in flyover phase, and preponderant at take-off.

The acoustics research efforts at TURBOMECA are therefore naturally carried out for operating powers corresponding to take-off and flyover ratings.

2.2 INFRARED DESIGN IN THE MILITARY RANGE

In the case of the infrared detectability of a military helicopter, the radiation source almost exclusively comes from the jet pipe and the turbine lower part of the installed engine(s). This signature is very important and directly endangers the helicopter survival during the operational phase.

After the first painful experiences of the Americans in Vietnam, who have lost more than 1 000 helicopters due to infrared detection, all the countries in the world have been trying to design helicopters having a low IR signature.

The race to improvements is without end, and any technological advance in the enemy homing heads creates new research in the protection of military aircraft ; the necessity of protection against IR detection is therefore obvious and research in this field will go on for a long time.

The US Army has issued a Military Specification to completely characterize the IR signature depending upon the emission angle and the various engine ratings.

Though greatly preponderant, the engine is not the only unit to radiate. In particular, the helicopter shape can play a non-negligible role in the IR radiation.

3. STUDIES AND TEST FACILITIES

3.1 ACOUSTICS

In any thorough study, it is necessary to have complete test means to look for the noise causes, analyse and test the various systems which will permit to reduce it.

3.1.1 Test means and acoustic characterization of a turboshaft engine

a) Test bed in a «free field» at PAU-UZEIN (see fig. 1)

This TURBOMECA acoustics test bed is located near PAU-UZEIN Airport : it is a complete test bed which permits to make measurements on all the Company engines, and more especially turboshaft engines up to a power of 1 700 kW.

The engine axis is at 3 metres of a concrete ground, uniformly reflecting. Measurements can be carried out at 10, 20 or 30 metres from the engine on a half-circumference.

As a general rule, records are taken on a radius of 20 metres with 3 microphones respectively located at about 0 m, 3 m and 6 m from the ground ; microphones are fitted to a trolley with automatic stop every 10^{o} for the measurement ; spectra are corrected in real time of temperature, relative humidity and ground reflections. Finally, we can obtain noise spectra close to the free field, in standard conditions.

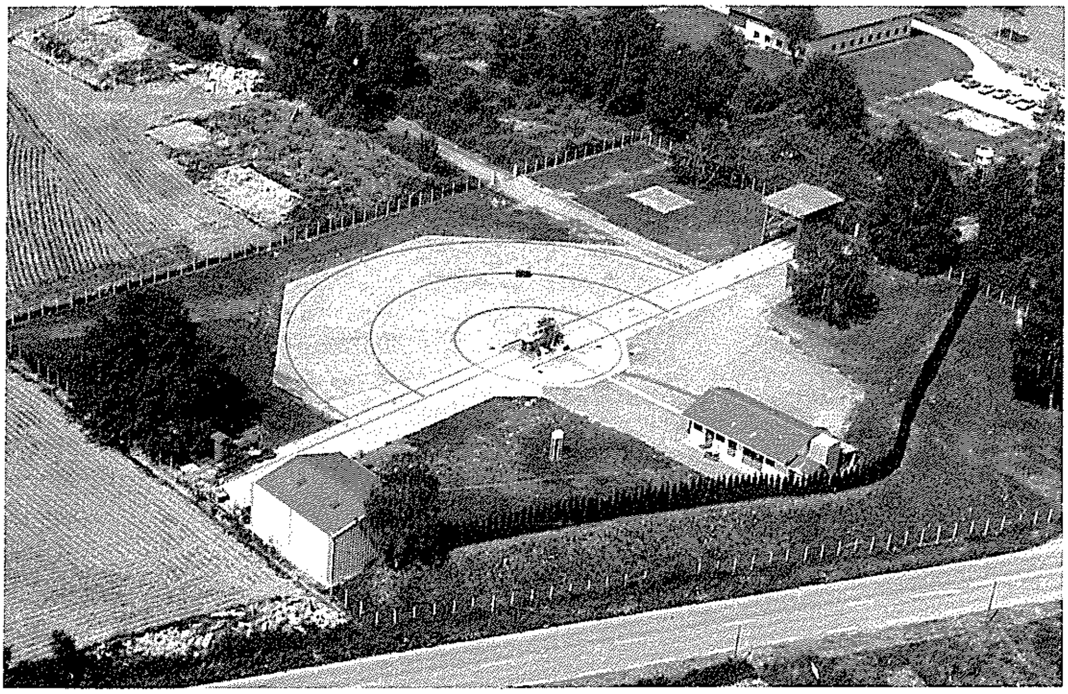

Fig. 1 — Test bed in a «free field» at PAU-UZEIN

In parallel to the acoustics measurements, we record and calculate the main thermodynamic parameters : power, consumption, temperatures, pressures ... in different points of the engine.

b) Double intensimetric probes(see fig. 2)

Used generally on the UZEIN test bed, we have designed a trolley on a rectilinear rail, equipped with two intensimetric probes installed at right angles.

It is then possible to know, on a parallel axis to the engine axis, the direction and intensity of any noise.

c) Internal probes (see fig. 3)

We have established, in cooperation with the «Office National d'Etudes et de Recherches Aérospatiales» (National Design and Aerospatial Research Centre) a localisation technique of noise sources with internal probes.

These probes are of the wave guide type which can be located in any part of the engine, in the air flow wall. To prevent the reflections of the noise wave, ONERA has designed wave guides with a very long length : approximately 30 metres.

The measurement principle is to make a cross analysis between two inner probes, in the same plane of the engine (in order to eliminate the non correlated noises) and an external microphone, in a far field ; this measurement principle is called the 3 sensor technique.

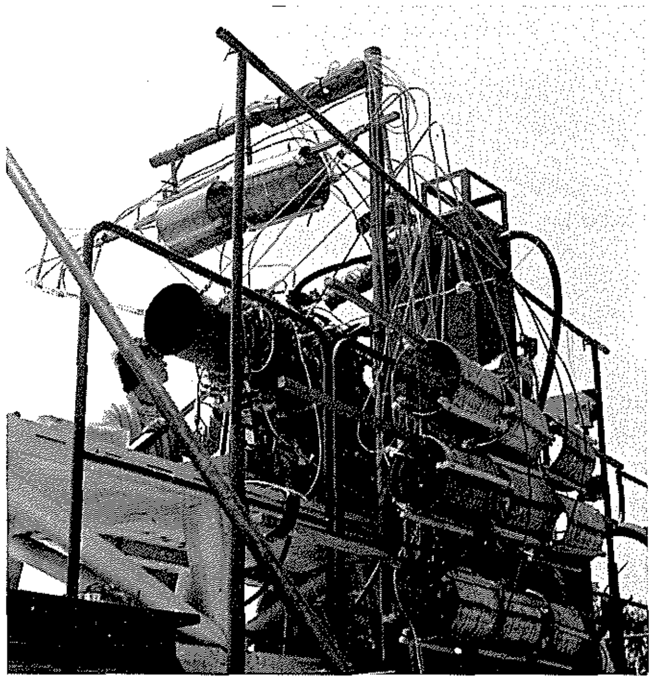

Fig. 3 — Internal probes

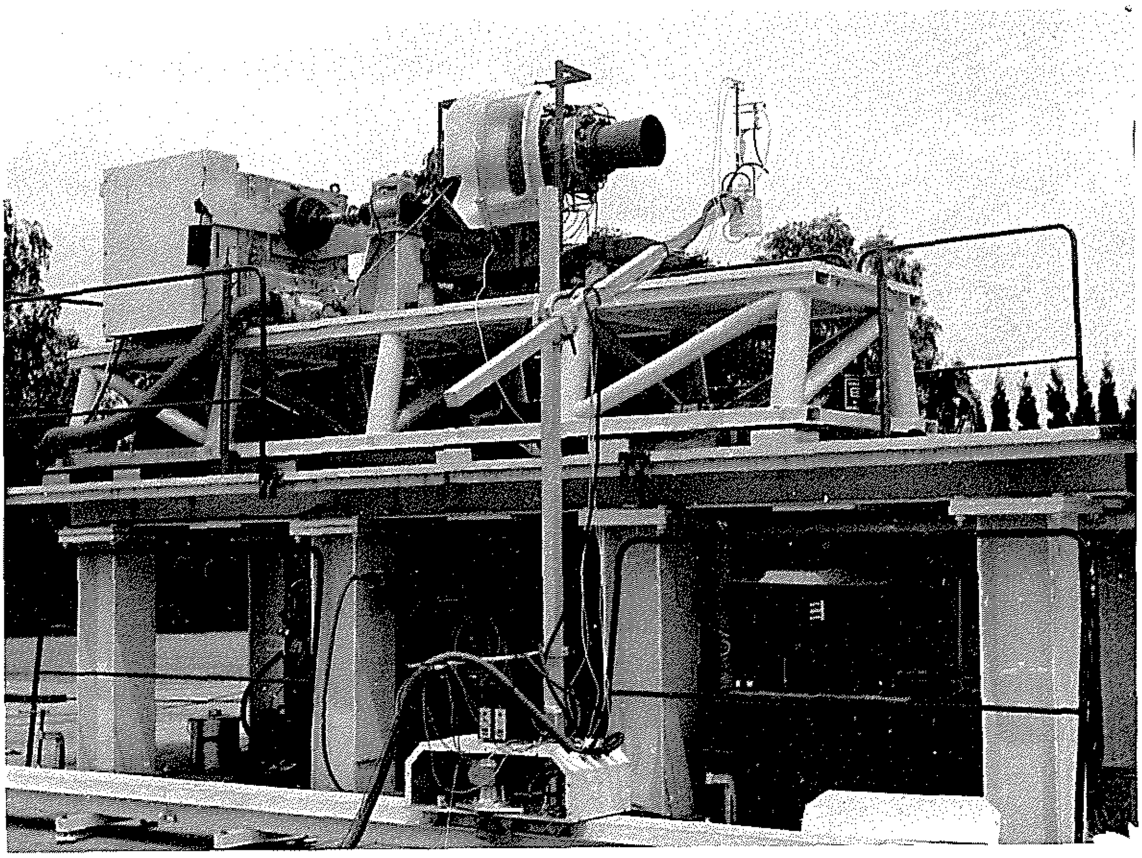

Fig. 2 — Double intensimetric probes

d) Air intake and ejection silencers (see fig. 4)

An other way to better define the sources of a turboshaft engine at the UZEIN test bed is to carry out a «separation of sources» with air intake and ejection silencers.

3.1.2 Noise study of a turboshaft engine

The TURBOMECA Company has been studying the noise of turboshaft engines for many years.

At present, our Research efforts are centred in 3 directions.

a) Variation of the number of blades of a compressor.

The compressor radiation essentially depends upon its first stage. The blade number increase, in acceptable limits for performance and for the development of the compressor wheel, is always beneficial for two reasons :

- the rotor natural frequency increases and can reach a value exceeding the limits of the standards in force (> 11 200 Hz).

- the chord is reduced (for an axial wheel), the effect being an appreciable reduction of radiated power.

b) Sound-proofing

Before any specific study, it is necessary to understand the mechanism of noise generation, from the theoretical point of view ; these studies have permitted to develop a dimensioning method for acoustic materials of the resonator type, and to estimate the efficiency of a sound-proofing.

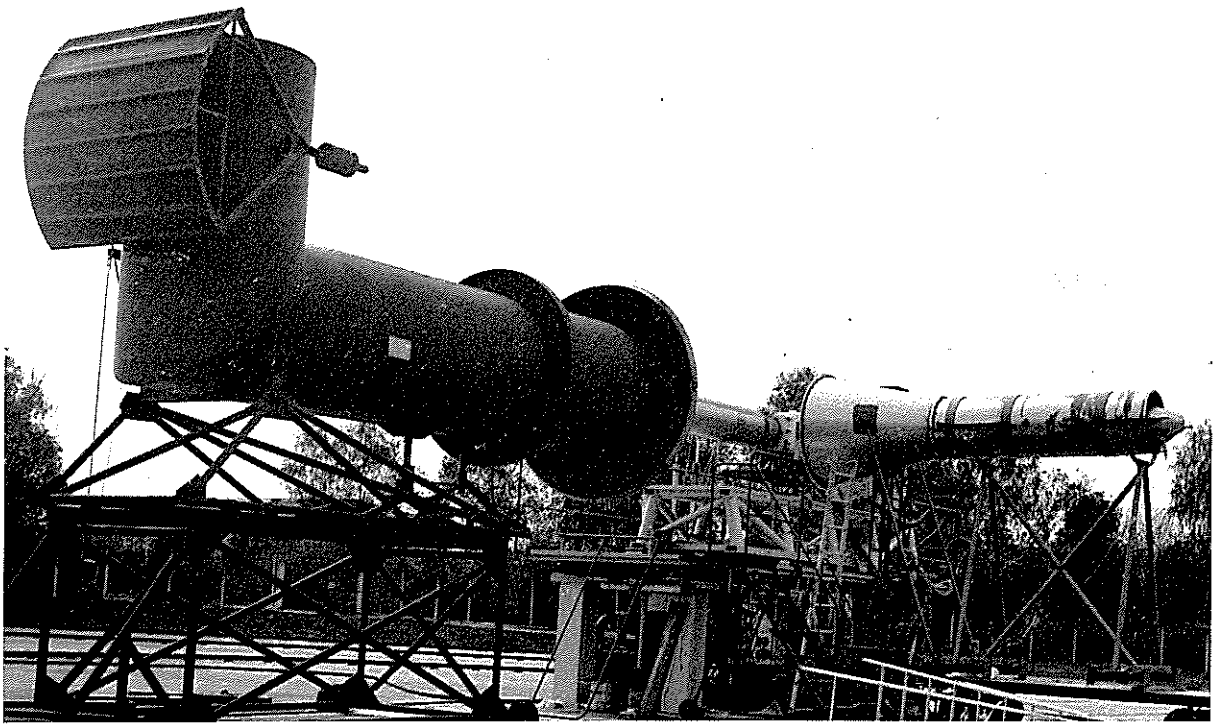

Fig. 4 — Air intake and ejection silencers

c) Analytic formulation of noise sources (see fig. 5)

Our very complete data bank and studies on the mechanism of noise generation have permitted to show up 5 noise sources, each one having a relatively well delimited frequency range : the compressor noise, internal noise, combustion noise, turbine noise, casing noise.

By definition : the internal noise is the difference between the noise emitted at ejection minus the jet noise, and the casing noise is the difference between the global noise emitted by the turboshaft engine minus the air intake and ejection noise.

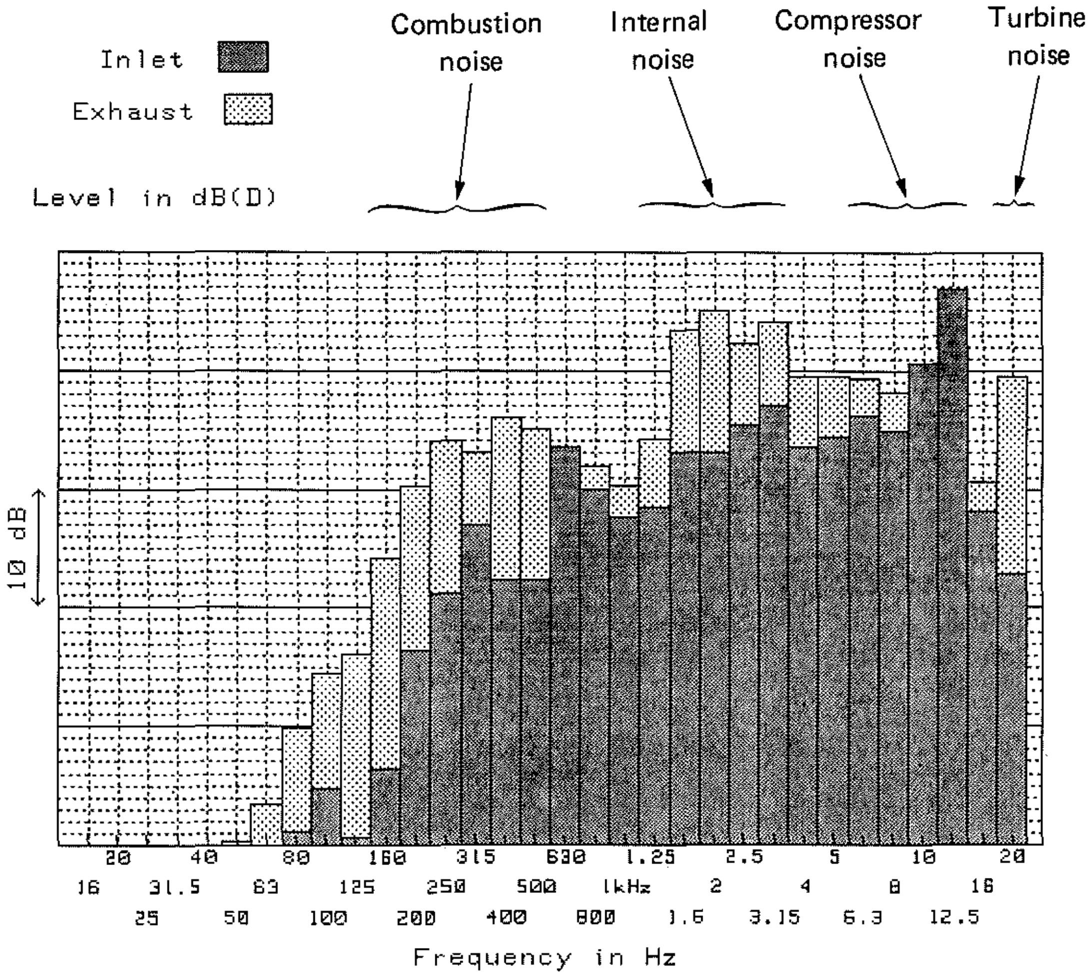

Fig. 5 — Various noise sources

3.2 INFRARED

As in the field of acoustic signature, the IR studies must be completed by an experimentation at full scale.

3.2.1 Test and characterization facilities of a turboshaft engine in the infrared field.

a) PAU-UZEIN test bed

As the infrared research started later than acoustic studies, naturally we have adapted the UZEIN test bed to permit characterizing and studying the various systems concerning the reduction of the infrared signature of our engines.

We measure the IR radiation at 10 metres of the jet pipe and on a circumference of 360°.

The engine being installed high up, we have installed a mobile platform supporting a thermography camera ; the axis of the lens is at 3 metres from the ground as the engine axis (see fig. 6).

It is a twin channel camera permitting a measurement in two wave length bands : S.W. and L.W. (short wave length and long wave length).

In the same way as in the acoustic field, we measure the IR signature of the turboshaft engine and, at the same time, we record the main thermodynamic parameters. We carry out various calculations in the outlet plan of the jet pipe (mean temperature, mean speed,etc ...).

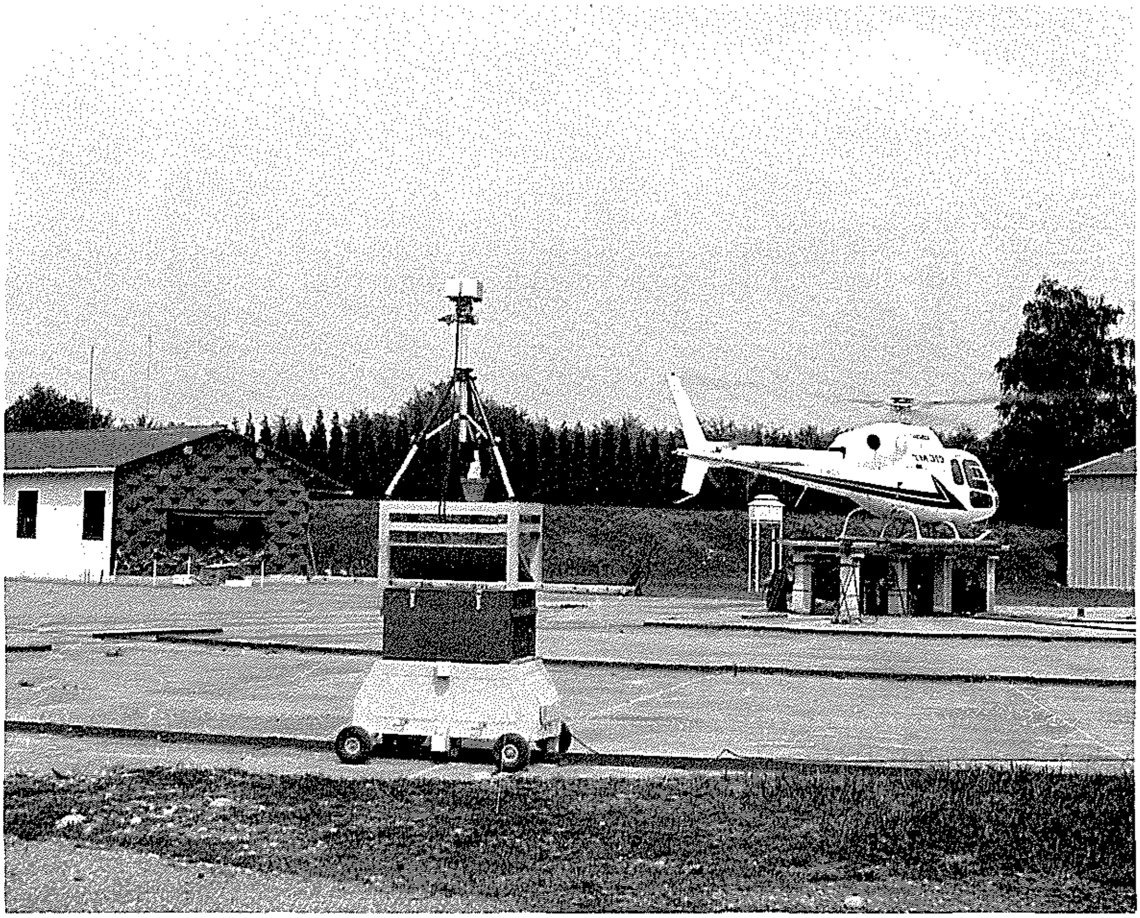

Fig. 6 — IR camera in PAU - UZEIN test bed

b) Emittance and emitted energetic intensity

The only measure of an infrared image has little interest to characterize and quantify the radiation of a system. To calculate the emittances emitted by the turboshaft engine, it is necessary to define, a priori, a certain number of rules.

In particular, we define the emitted emittance from solid parts in band II between 3.7 and 4.8 μm.

In addition, we take into account the ambient temperature and we calculate the reduced value of emittance, brought to 15^{o} C standard ; the IR radiation is therefore practically independent of the measurement moment.

The energetic intensity emitted from a jet or from a solid part is calculated taking into account a standard value of landscape background.

3.2.2 Study of a turboshaft engine infrared radiation

The infrared problem has been concerning TURBOMECA for approximatively 5 years. The design of new military projects has led us to study the infrared suppressor system, capable of reducing the detection distance of new generation missile homing heads.

In parallel, we have created a data bank for our preliminary studies on the radiation forecast.

a) Design of infrared suppressors

The infrared signature of the jet and solid parts essentially depends upon 3 parameters :

- temperature
- emission coefficient
- radiation surface

The design of the infrared suppressor (or more exactly of an infrared reducer) must take into account these 3 parameters. The simple target to reduce temperature by the dilution effect is quite insufficient.

In particular, in the case of solid parts, the emissivity of the material and the visible surface by the homing head is fundamental in the radiation of the energetic intensity.

We have therefore developed a calculation code permitting the research of an optimal system by variation of geometric parameters; this calculation code is completed by the schematic diagram of the suppressor.

b) Data bank - IR radiation forecast

Our data bank groups the whole of the thermodynamic and infrared results obtained on turboshaft engines of very different power ranges. These results have been completed by IR measurements on helicopters.

These helicopters have been installed on the platform of the PAU-UZEIN test bed at 1.5 metre from the ground.

4. A FEW SIGNIFICANT RESULTS CONCERNING THE AC SIGNATURE

Among the latest developments, with respect to the reduction of the acoustic signature of our turboshaft engines, we present 2 really significant results concerning :

- the increase of blade number in a compressor
- the modification of the central cone attachment fittings of an exhaust pipe.

a) Increase of compressor blade number

The study has been carried out on the 1st axial stage of the MAKILA turboshaft engine (see fig. 7).

The test of a wheel with 29 blades (increase by more than 50% by comparison with the production wheel with 19 blades) has permitted a reduction of 4.6 TPN dB at the max. directivity angle at a distance of 20 metres circumference.

This acoustic gain did not appreciably alter the engine thermodynamic performance.

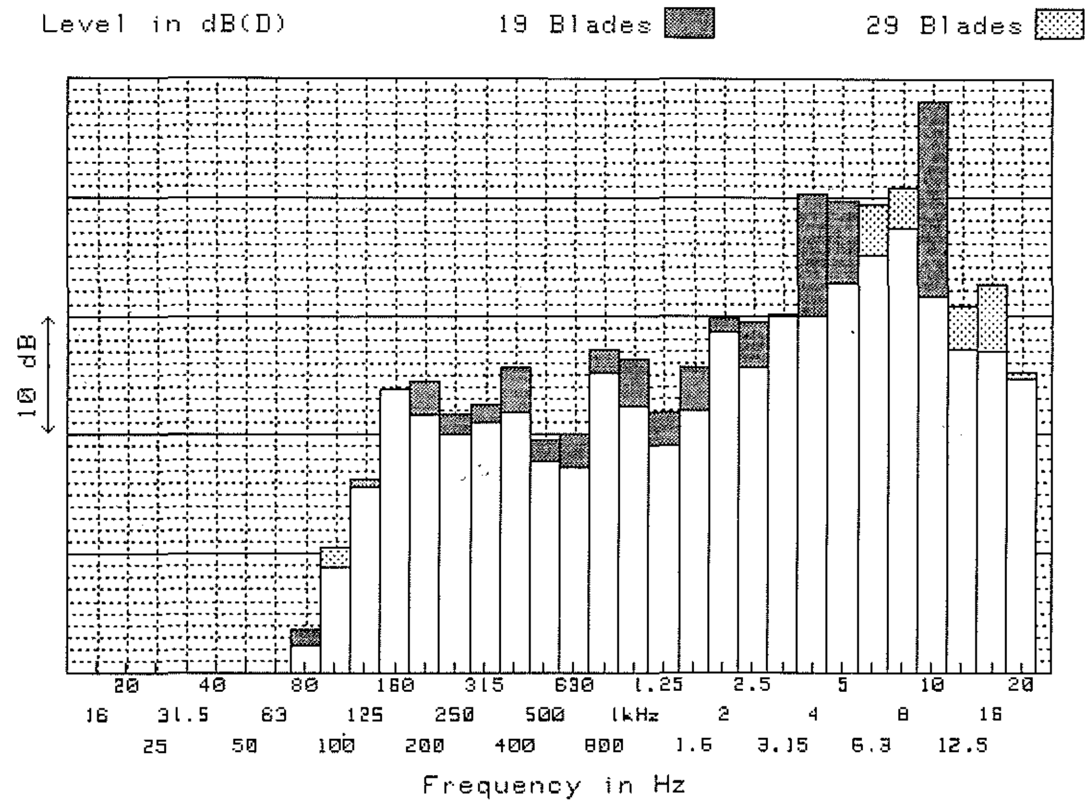

Fig. 7 — Comparison in 1/3 octave of noise spectra between axial compressor wheels with 19 and 29 blades

b) Modifications of the exhaust pipe cone attachment fittings (see fig. 8)

One of the main sources of internal noise is the interaction noise between the turbulent flow at the free turbine oulet and the obstacles encountered in the exhaust nozzle.

At 150 metres, in side (conditions close to ICAO standards) the modification of the TM 333 jet pipe cone attachment fittings has permitted an appreciable reduction of 5.4 TPN dB.

Here also there was no undesirable effect on engine performance.

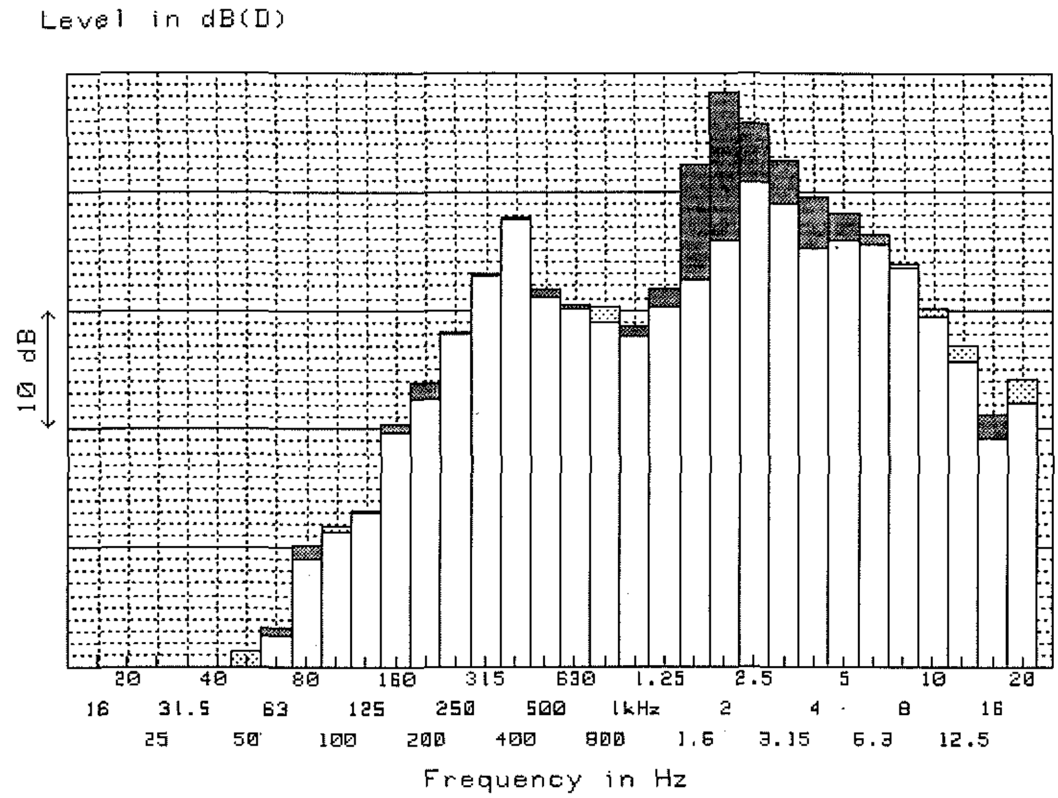

Fig. 8 — Comparison in 1/3 octave of noise spectra between 2 jet pipe types

5. CONCLUSIONS

Naturally, Research and Testing on acoustic and infrared discretion will continue at TURBOMECA.

Concerning civil acoustics, a lot of research remains to be done before the helicopter can fly, without excessive disturbance in the centre of cities. It is a long term target, but not impossible. Actions to be undertaken will be carried out on the helicopter alone (main rotor - anti-torque rotor ...) and on engines (air intake - exhaust ...).

Nevertheless it is certain that the intensity of studies will be greatly conditionned by the more or less important severity of standards, as well as international (ICAO) as local standards, specific to each state, or even to each heliport.

Concerning the infrared signature, the results obtained to decrease the radiated energetic intensity are encouraging but not sufficient.

- The weight of the system must be decreased
- Losses due to counter-pressure must be reduced
- At last, and not the least, the task is to design infrared systems which reduce the radiation of hot parts and jet efflux in all directions ; it is a really difficult problem.

At present, our Company is continuing research in this way.

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