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PERFORMANCE OF THE HIGH SPEED ANECHOIC WIND TUNNEL AT LYON UNIVERSITY

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16. Abstract

The characteristics of the feed duct, the wind tunnel and the experiments run in the convergent-divergent anechoic wind tunnel at Lyon University are described. The wind tunnel was designed to eliminate noise from the entrance of air or from flow interactions with the tunnel walls so that noise caused by the flow-test structure interactions can be studied. The channel contains 1 x 1 x 0.2 m glass and metal foil baffles spaced 0.2 m apart. The flow is forced by a 350 kW fan in the primary cirucit, and a 110 kW blower in the secondary circuit. The primary circuit features a factor of four throat reductions, followed by a 1.6 reduction before the test section. Upstream and downstream sensors permit monitoring of the anechoic effectiveness of the channel. Other sensors allow modeling of the flow structures in the tunnel. The tunnel has been used to examine turbulent boundary layers in flows up to 140 m/sec., turbulence-excited vibrations in walls, and the effects of laminar and turbulent flows on the appearance and locations of noise sources.

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PERFORMANCE OF THE HIGH SPEED ANECHOIC WIND TUNNEL AT LYON UNIVERSITY

By M. Sunyach, B. Brunnel, G. Comte-Bellot*

Abstract

This continually adjustable anechoic wind tunnel gives the following maximum speeds: /316*

160 m/s in a cross section of 0.4 m x 0.2 m

80 m/s in a cross section of 0.6 m x 0.4 m

35 m/s in a cross section of 1.4 m x 0.6 m

It has several specific technical characteristics:

1 The motor portion is on the upstream side which enables direct evacuation of the flow from the chamber thanks to a wall composed of an adjustable opening and movable baffles.

2 The jet feed system is of the bypass type which reduces the noise specific to the primary airflow at high speeds.

3 An associated system of lateral manifolds and passages with baffles controls the flow of the jets thus immensely reducing secondary flows which exist in the anechoic chamber.

The presentation points out the various aerodynamic and acoustic properties of the system, in particular acoustic insulation of the

*Numbers in margin indicate foreign pagination.

facility, the map of secondary flows, the chamber cutoff frequency, and the noise itself.

Some examples illustrating the research presently conducted on this test facility are then presented.

I. INTRODUCTION

Analysis of flow noise generation and radiation of structures excited by flows is greatly facilitated if one has available a test facility combining both a silent air input and an anechoic chamber.

There exist some set-ups of this type, in particular at the David Taylor Naval Ship Research and Development Center (Bethesda, USA), in several NASA laboratories (Ames, Langley, and Lewis, USA), at the National Gas Turbine Establishment (Farnborough, GB), at Dassault-Brequet (Velizy, France), and at the Ecole Centrale de Lyon. More recently, two more modern facilities were constructed:

the CEPRA-19 wind tunnel in Saclay and the Dutch-German (DNW) wind tunnel in the North Polder near Amsterdam. The operating principles employed vary from one facility to another: set-up in a closed system [1, 2, 3], use of an output manifold with an evacuation system [4], placing of the high pressure section on the upstream side [5].

This last principle was chosen for construction of the new test facility built at the ECL. It has several advantages:

. Possibility of having a large anechoic chamber free of any obstacles such as pick-up manifolds;

. Good acoustic and aerodynamic control of the airflow arriving in the chamber;

. Direct elimination of the flow after traveling through the chamber;

. Possibility of setting up several coaxial or adjacent jets in order to reduce the noise level of the primary jet such as in aeronautical bypass systems;

. Possibility of combining lateral air inputs in order to supply the jets with drawn air and to thereby reduce the recirculation flows which would exist in the confined space.

This report presents the properties of the chamber, the wind tunnel, and some examples of use of the test facility.

II. DESCRIPTION OF THE FACILITY

The wind tunnel is shown in its entirety in Figure 1 and essentially consists of the following from upstream to downstream:

- Acoustic baffles* on a cross section of 4 m x 3 m and a depth of 3 m;

- Rotor nozzle centrifugal fans manufactured by NEU, having a power rating of 350 KW for the primary system and 110 KW for the secondary system;

* All the baffles used are supplied by Francisol and are made from two densities of mineral wool covered with a glass fabric or a metal foil. The basic element measures 1 m x 1 m x 0.2 m. The space between baffles is generally 0.2 m.

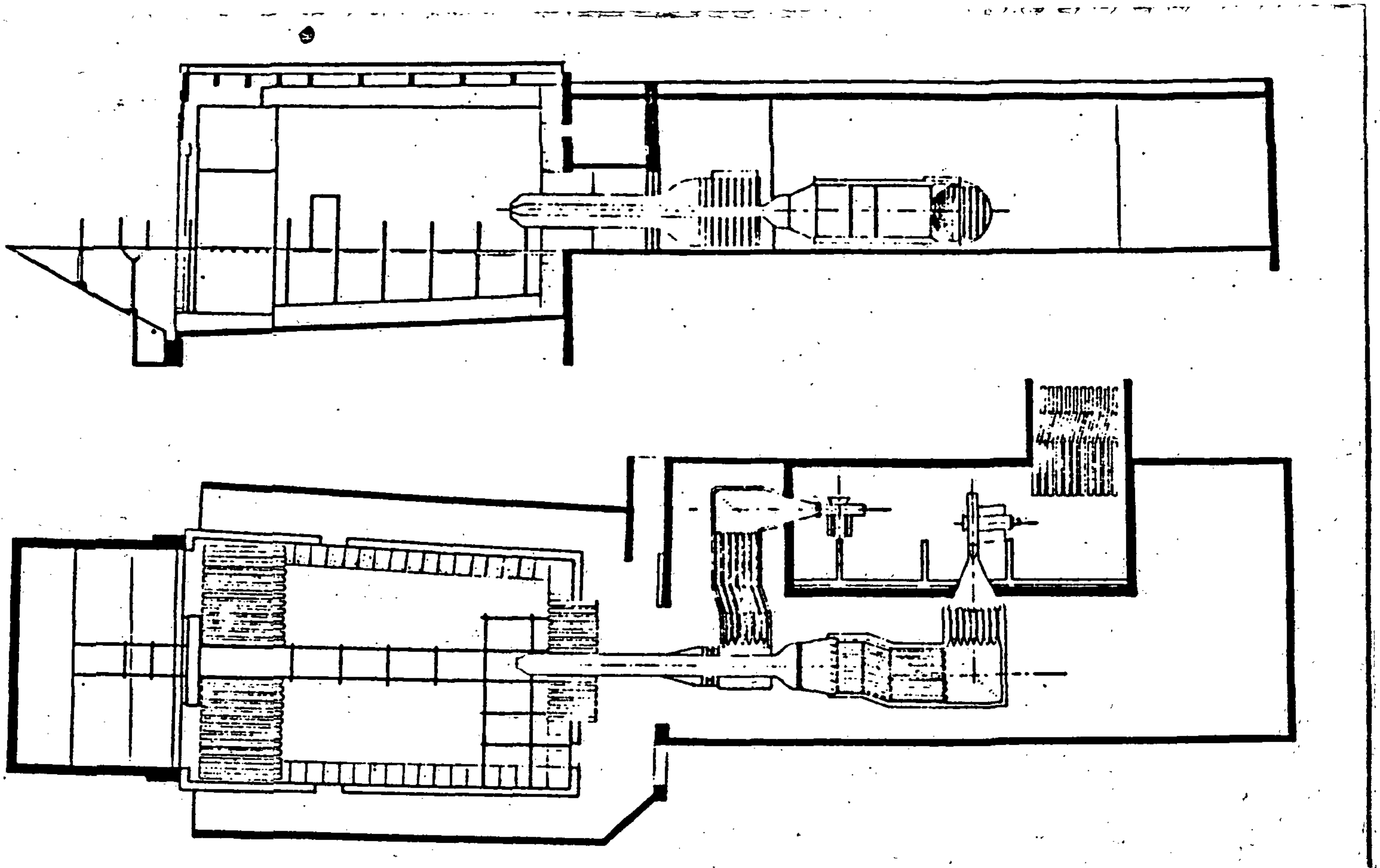

Figure 1

Sketch of new high-speed anechoic wind tunnel at the Ecole Centrale de Lyon

- Acoustic baffles placed in the ducts over a 5-meter length for the primary system and a 4-meter length for the secondary system;
- The subdivision system of the secondary airflow on either side of the primary system;
- Grids and honeycomb structures;

- An initial reduction with a ratio of 4 for the primary airflow as well as the secondary airflows;

- A second reduction at the input of the flows into the chamber with a ratio of 1.6 for the primary system and 1.4 for the secondary system;

- Jet nozzles with a reduction of 3.9 for the primary jet (with an output cross-section of 0.4 m x 0.2 m) and a reduction of 2.8 for the two secondary jets combined (with an output cross-section of 2 x 0.4 m x 0.2 m).

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The anechoic chamber with its slightly diverging walls has the following average effective dimensions: 10.3 m, 8 m, and 7.6 m. It is semi-buried except for the face opposite the jet input which is made up of 3 rows of 26 vertical baffles (thickness 0.2 meters; total depth 3 meters) on a cross-section of 8.15 m x 8.4 m. The air can pass between the baffles and, what's more, the middle row of baffles is set on a sliding mount in order to free a central opening of 3.20 m x 2.20 m which is used for direct evacuation of the jet to the outside. The five other faces are covered on the inside with fiberglass in panels 40 mm thick and 450 mm, 675mm, and 850 mm long, and a density of 37 kg/m^3 and 70 kg/m^3 combined with a base mesh measuring 0.60 m x 0.60 m.

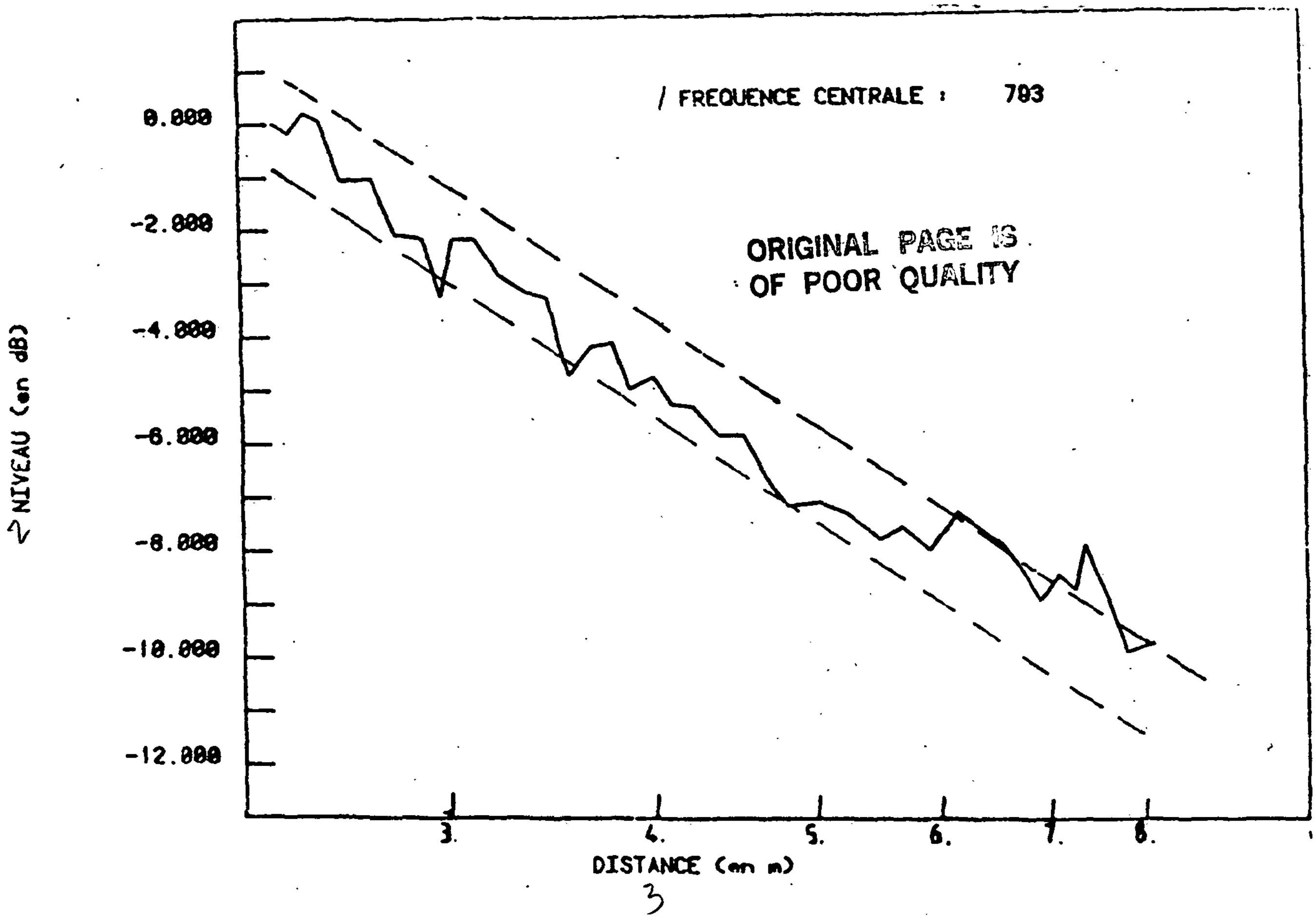
Two open lateral channels on the exterior (cross-section of 2 m x 1.5 m) are arranged on either side of the chamber and communicate with acoustic baffles surrounding the airflows right at their input into the anechoic chamber on a cross-section of 3 m x 3.50 m and a depth of 2 m. These channels supply the jets with drawn air (cf. chapter VI).

A grating which can be moved over its largest portion provides for communication with the chamber. It can reach the outside so that machines to be tested in the chamber can be brought in. Support bars and attachment points are used to mount the various pieces of measuring equipment which must be put in the chamber.

III. ANECHOIC PROPERTIES OF THE CHAMBER

The anechoic nature of the chamber was analyzed by measuring the decrease in the sound pressure from a near monopolar source (loud speaker, Focal 5N 81 dB, diameter 13 cm, in a small closed box) with emissions in the 40 Hz to 4 kHz frequency range. Two Neutrik electret microphones of the 3281 type are used, one stationary 1 meter to the downstream side of the source and the other movable. Two decrease directions were explored in the horizontal median plane of the chamber: the longitudinal direction toward the baffles and the crosswise direction toward the lateral walls.

In an initial phase an impulse emitted by the loud speaker is digitally recorded (transiscope DIFA TR 1030, 1 MHz sampling) so that the microphone emitting distance can be determined. Next, a wide band measurement is made using a two-channel FFT analyzer type HP 3582 A. The results are then processed by a PDP 11-03 minicomputer in order to give the results in thirds of an octave and automatic plotting of the decreasing curves.



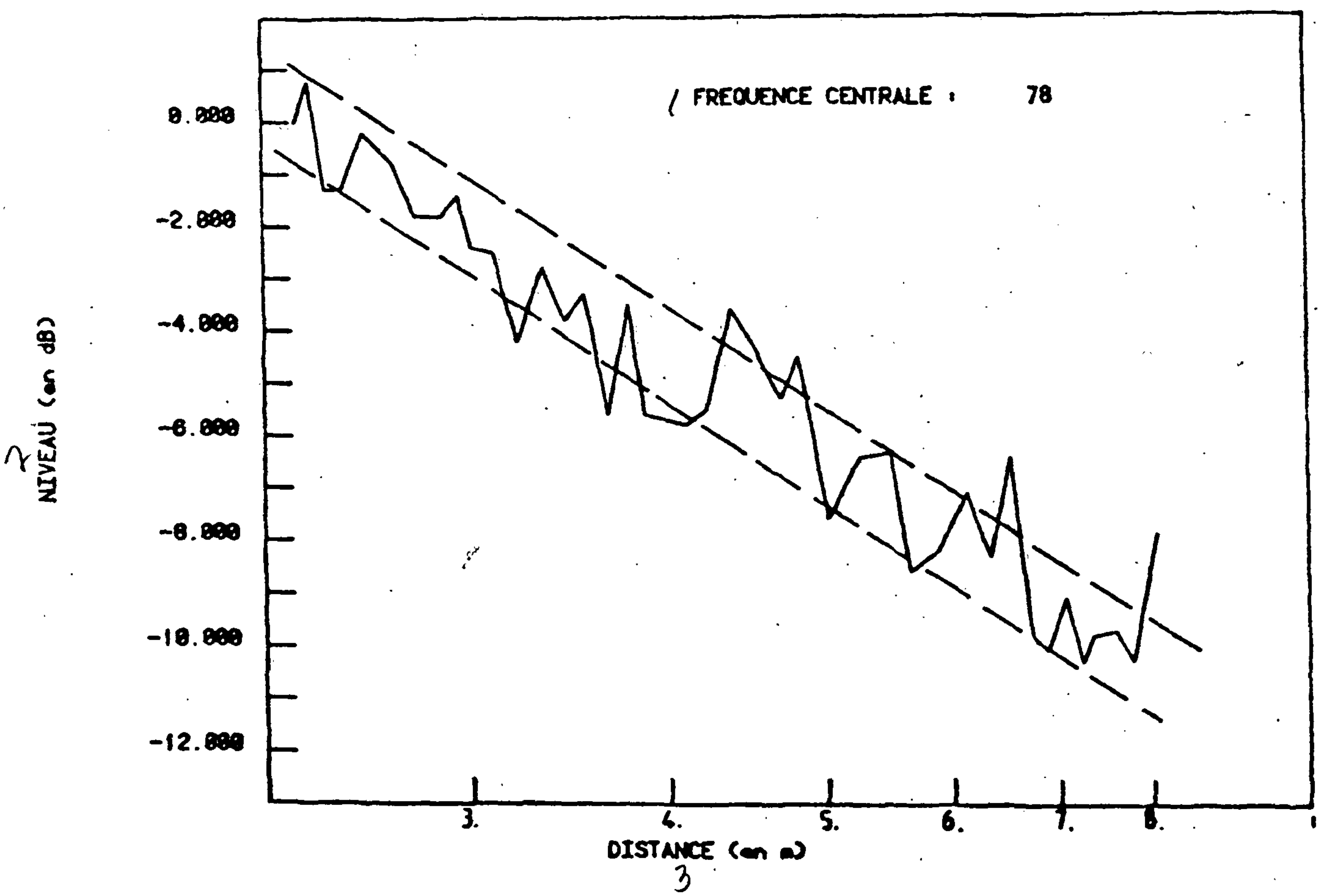


Figure 2 - Example of free field decay (in the longitudinal direction)
(Please see key on following page)

Key to Figure 2

1: Central frequency   2: Level (in dB)   3: Distance (in meters)

The results obtained for the longitudinal direction and for two typical frequencies N = 78 Hz and 783 Hz, are presented in Figure 2 with indication of the theoretical decrease in 1/r and a bandwidth precision of ± 1 dB. In spite of a slight reflection which occurs on the baffles at low frequencies, the anechoic nature of the chamber is good for N approximately greater than 75 Hz, even in the direction in which the acoustic response of the baffles was not known previously.

V. AERODYNAMIC CHARACTERISTICS OF THE OUTPUT AIRFLOWS

The average speed profiles were determined at the output of the jets at a point level with the covering for the large section of the airflow and 1 meter from this point when the nozzles mentioned in § II are in place. The results obtained are given in Figure 3 and show that by acting on the speeds of the primary jet and the secondary jet respectively we can obtain:

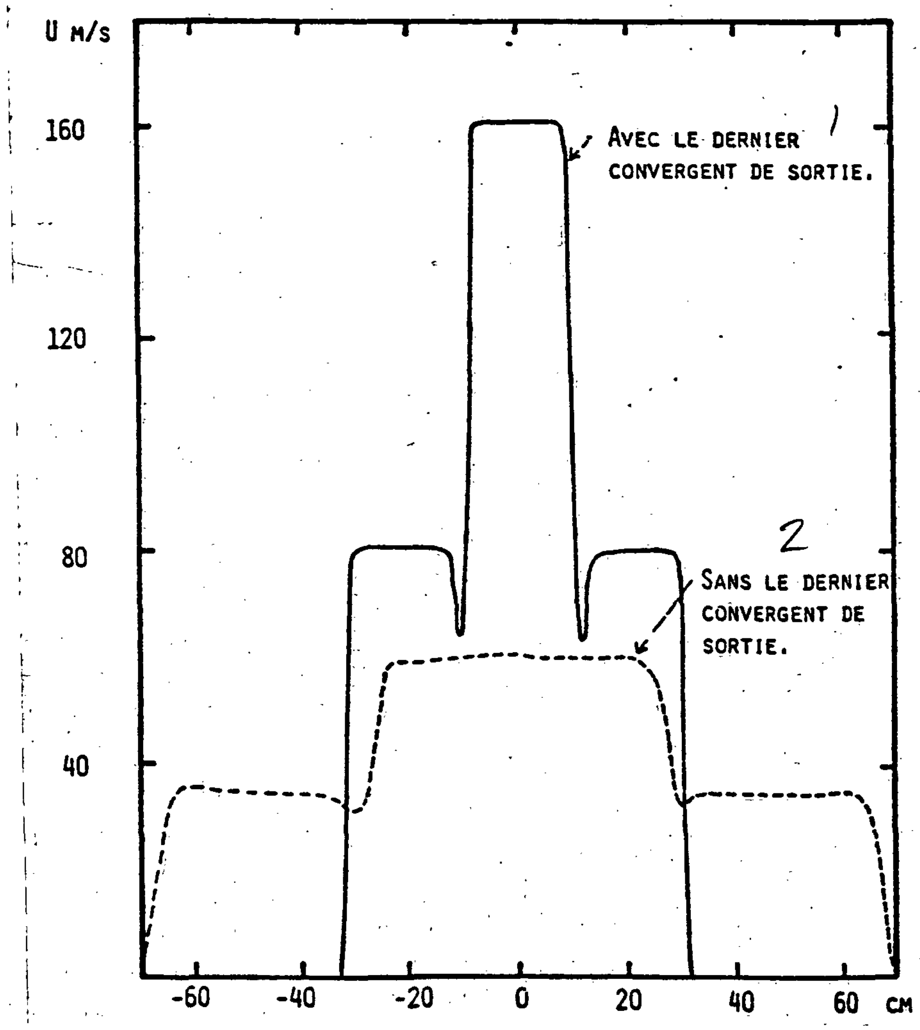


Figure 3

Average speed profiles at nominal operation of the facility recorded at the jet outlet, with and without the final outlet nozzle described in § II

Key to Figure 3

1: With the final convergent nozzle 2: Without the final convergent nozzle

160 m/s for a cross-section of 0.40 m x 0.20 m with two adjacent flows of half that speed

80 m/s for a cross-section of 0.60 m x 0.40 m.

35 m/s for a cross-section of 1.40 m x 0.60 m.

The ratio $\lambda = U_S/U_P$ of the secondary speed to the primary speed (= 0.5 at nominal operation) as well as the ratio B' of the secondary section to the primary section (in this case set at B' = 2) are defined by searching for an acoustic optimum of a bypass system, cf. [6, and 7] and § VII.

The preturbulence level of the flows is 0.2% at the outlets of the jets and 0.4% at the input of the airflows in the chamber. The measurements were made according to the traditional method with a hot wire anemometer: a ten-micron tungsten wire, 0.8 overheat, DISA 55 D01 constant temperature anemometer.

The potential lengthening of the cone of the primary jet under the effect of the secondary adjacent jets is being studied. The first tests indicate that even without the lateral jet guide baffles it is about 30%.

V. ACOUSTIC DAMPING OF THE DUCT SILENCERS

The acoustic damping which may be provided by the duct silencers was studied by placing a noise source in the machinery room and by measuring the remaining sound levels on the downstream side in the anechoic chamber at the center of the primary jet nozzle. The measurements are made by thirds of an octave using a BK 4145 1" microphone and a BK 4417 analyzer.

As an additional feature the damping of the concrete wall of the machinery room (0.2 m thick) and the acoustic door which is integral with it was determined with the same auxiliary noise source. The results are presented in Figure 4.

By using this damping applied to the maximum noise level created by the fans in operation, we can estimate the interference noise level in the chamber during real operation of the facility. The results are given in Figure 5 (curves no. 1 and no. 3 respectively). For purposes of complementarity and cross-checking, the damping effect of the machinery room concrete wall was also evaluated in the same way (curve no. 2) and compared with a measurement (curve no. 2'). The difference between 2 and 2', having a maximum of 10 dB, is understandable because when the fans are operating one can expect an acoustic radiation of the beginning of the envelope located outside the machinery room. The difference between curves no. 2 and no. 2' gives us an idea of the

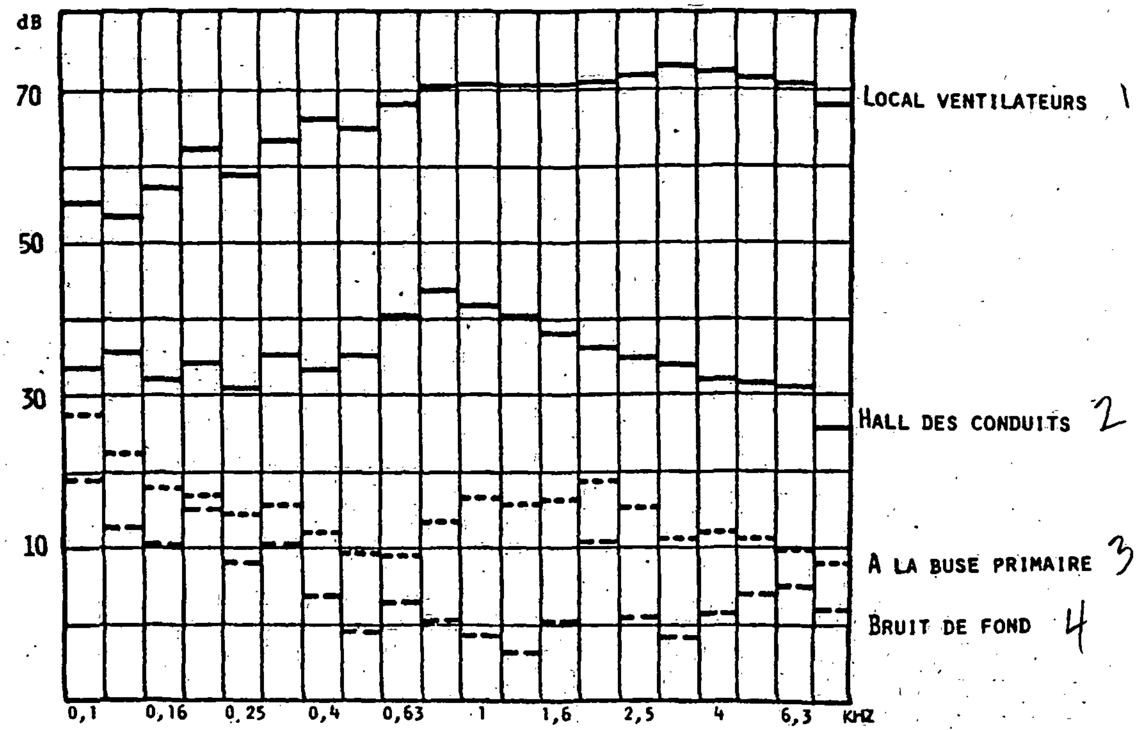


Figure 4

Acoustic Transmission loss of in-duct silencers

Measurement with an acoustic source located in the machinery room

Key to Figure 4

1: machinery room 2: duct chamber 3: at the primary nozzle 4: background noise

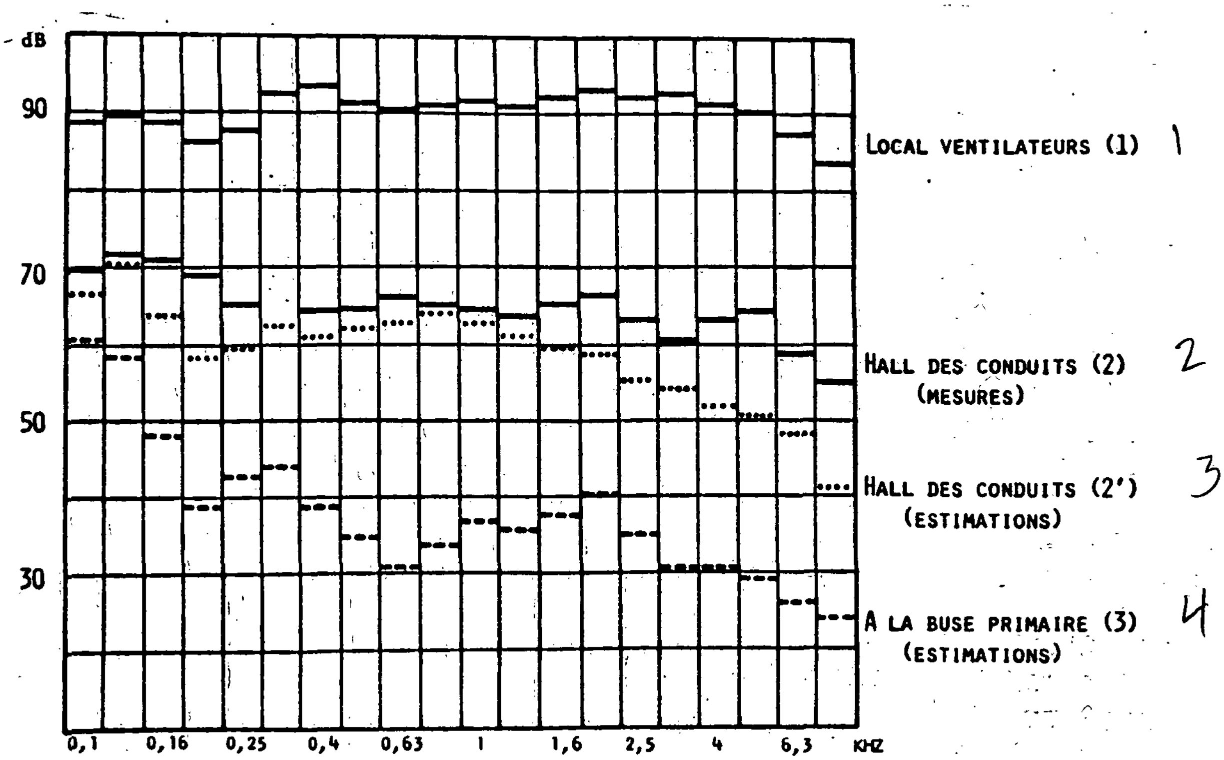


Figure 5

Acoustic Transmission loss of in-duct silencers

Estimates deduced from Figure 4 for nominal conditions of the fans

Key to Figure 5

1: machinery room (1) 2: duct chamber (2) (measurements) 3: duct chamber (2') (estimations) 4: at the primary nozzle (3) (estimations)

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maximum error on the evaluation of curve no. 3. The effectiveness of the silencers is therefore greater than 30 dB as of 160 Hz and greater than 50 dB beyond 500 Hz, which enables a residual level in the vicinity of only 40 dB (in each third of an octave).

Lastly, the background noise of the chamber was measured while all noise sources were stopped. The absolute levels obtained in thirds of an octave are also indicated in Figure 4.

VI. SECONDARY FLOW MAPS IN THE CHAMBER

The secondary flows were measured in the median horizontal plane of the chamber using an Anemotherm probe equipped with a clinometer with the wind tunnel operating at its nominal speed (primary airflow at 160 m/s, secondary airflow at 80 m/s). Two configurations were compared: one with the lateral manifolds closed (Figure 6) and one with the lateral manifolds open (Figure 7) in which case a speed of 2.80 m/s is produced. One can clearly see that when the supply of the jets is allowed through the acoustic baffles surrounding the nozzles, a reduction by a factor of about 2 occurs at nearly all the points explored. The flows do not exceed 1 m/s in the entire useful zone for the acoustic measurements (some checks in the median vertical plane of the chamber are presently being made). It can also be observed that in a relatively large zone the speeds are even lower (approximately less than 0.20 m/s) enabling fairly simple use of acoustic probes of the interferometry type and vector acoustic intensitometers.

VII. ACOUSTIC EFFECTIVENESS OF THE BYPASS SYSTEM

The acoustic gain of the bypass system was checked by overall level measurements and spectrum measurements. In these tests the microphone (1/2" BK 4133) was placed in the vertical plane of symmetry of the jets 1.5 m above the horizontal median plane and 1 m downstream of the jet outlet plane. The spectrums were obtained with a Hewlett Packard 3582 A analyzer.

In the first series of tests the noise level of just the primary jet, J_1, and the noise level of both the primary jet and the secondary jets, $J_1 + J_2$ were measured for various speeds of the secondary jet. The results are indicated in Figure 8 for two values of the primary speed (160 and 80 m/s). The small speed naturally enables the minimum noise for λ= 0.5 and the 6 dB increase which appears

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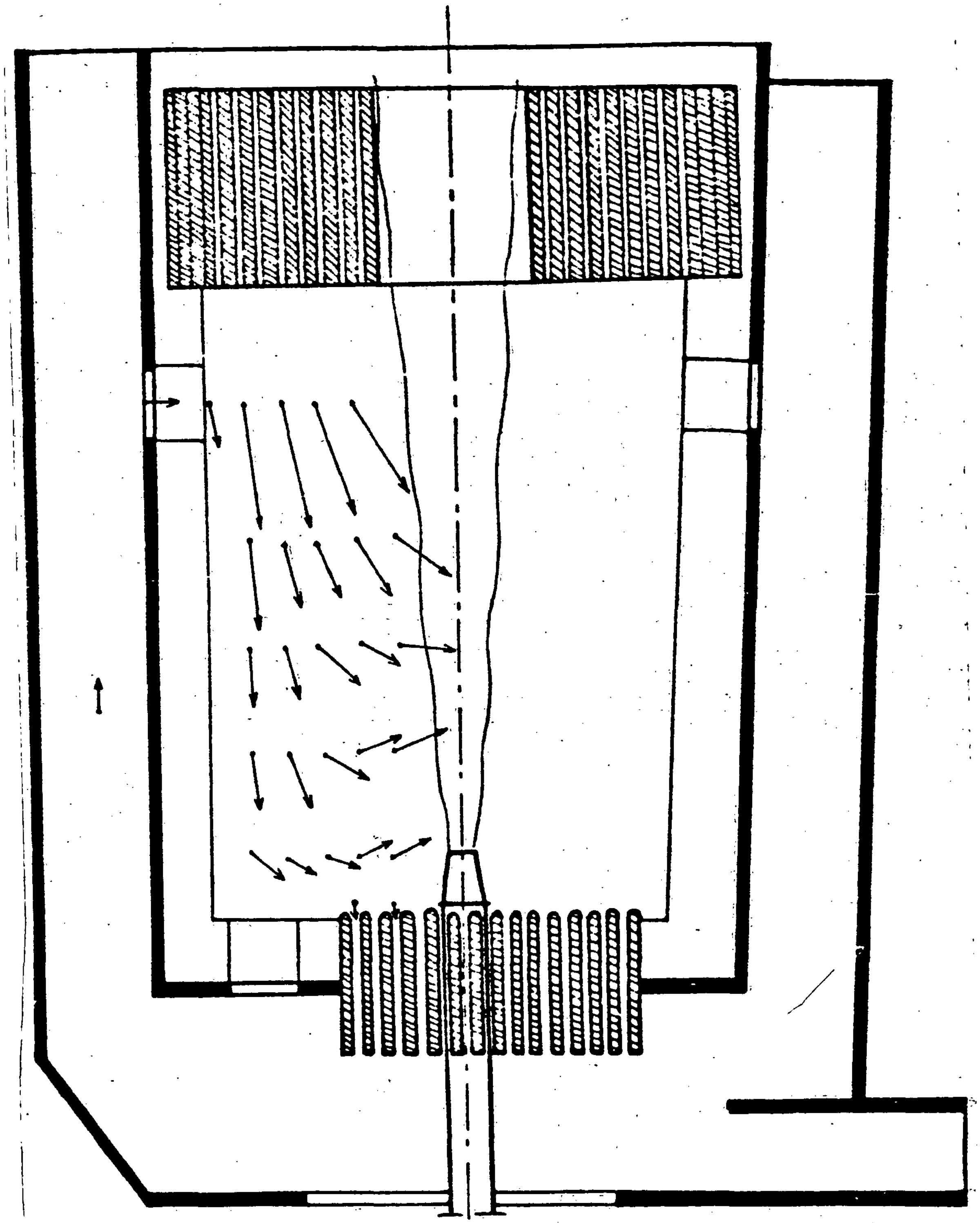


Figure 6 - Map of secondary flows when the lateral channels are closed

Scale: 2 cm for 1 m/s

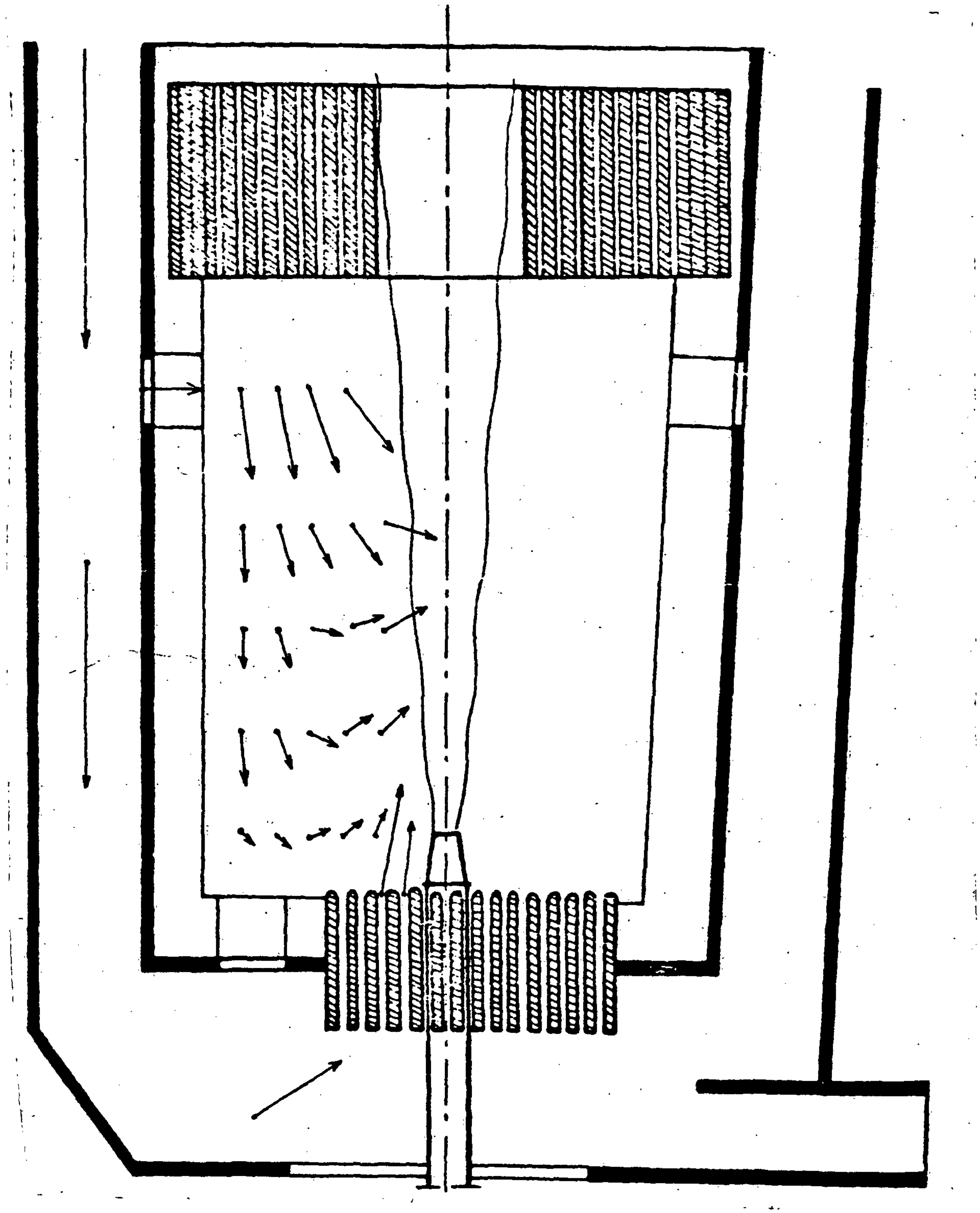
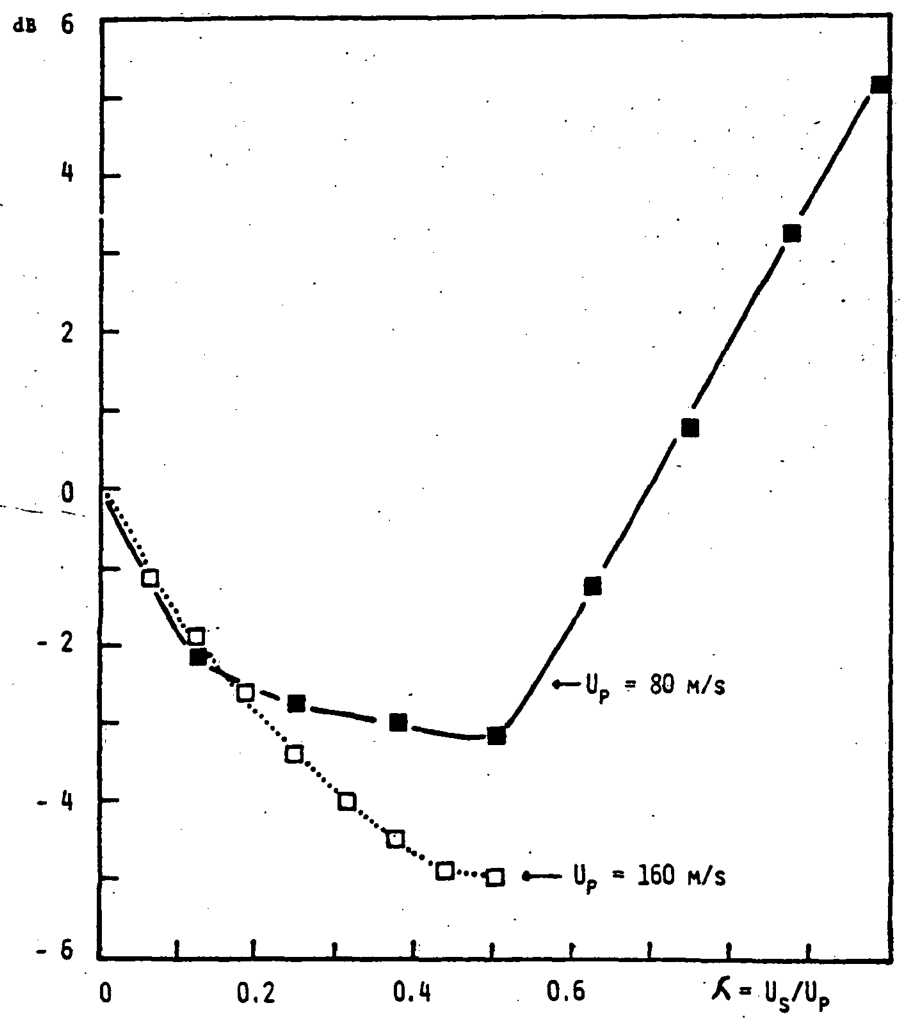


Figure 7 - Map of secondary flows when the lateral channels are open

Scale: 2 cm for 1 m/s

for $\lambda = 1$ to be highlighted since the B' ratio of the secondary cross-sections and the primary cross-section is equal to 2. The optimum reduction achieved by the bypass system (5 dB) corresponds to that which preliminary testing on a small scale had revealed [7] and which theoretical analyses [6], [7] had pointed toward.

The acoustic spectrum of the primary jet and secondary jet combined, $J_1 + J_2$, was compared to the acoustic spectrum of just the primary jet, J_1, for the largest speed available U_p = 160 m/s (cf. Figure 9). A substantial drop (5.5 dB) in the noise of the bypass configuration over a large frequency range of 50 Hz to 10 KHz is observed.



(PLEASE SEE FIGURE CAPTION ON FOLLOWING PAGE)

Figure 8

Acoustic gain of the bypass system for two primary jet speeds

Note, however, that if the thickness of the wall separating the primary and secondary flows is too small, it induces a discrete frequency in the 1 to 3 KHz range. As concerns the results indicated in Figure 9,

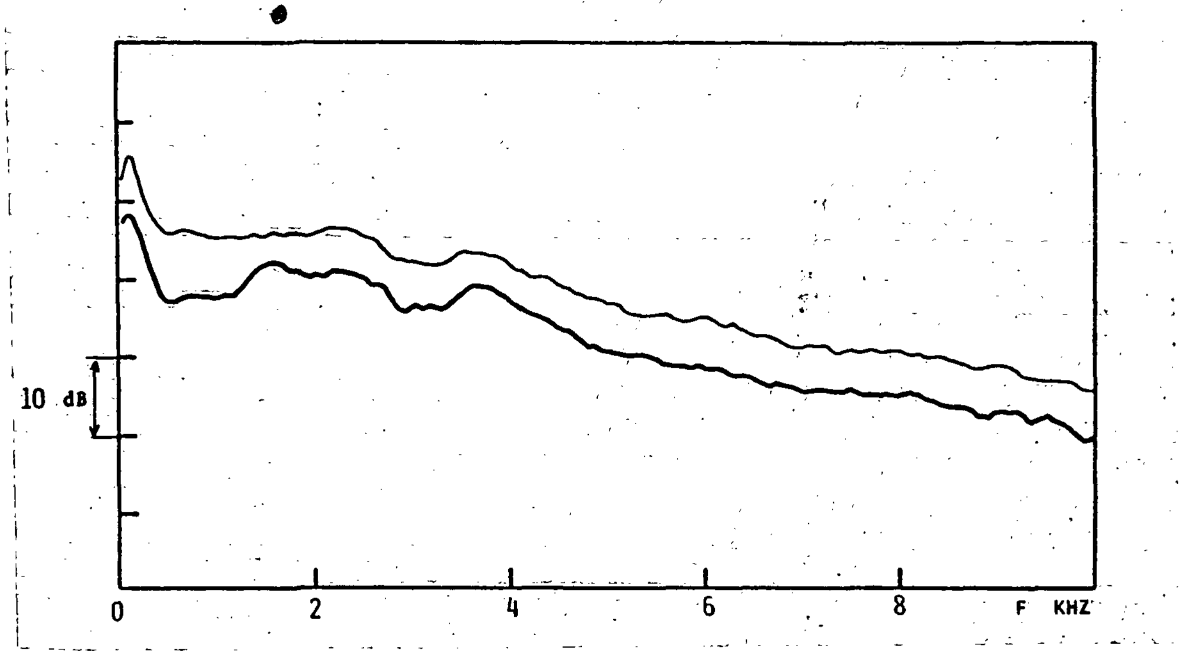


Figure 9

Gain for acoustic spectrum of bypass system

(Primary speed 160 m/s)

this thickness was increased to 10 mm, which causes these interfering peaks to disappear almost entirely.

VIII. EXAMPLES OF USAGE OF THE FACILITY

Several items of research have already been conducted in the wind tunnel:

- Study of the parietal pressure fields under the turbulent boundary layers up to 140 m/s. In particular, the very low level of the interfering signals (upstream noise, wall vibrations) was a very interesting property of the facility [8] (in cooperation with Metraflu);

- Study of the vibro-acoustic response of walls excited by turbulent boundary layers and analysis of the phenomena of coincidence between the aerodynamic convection speed of the exciting field and the speed of the deflection waves in the plate [8] (in cooperation with Metraflu);

- Study of the effect of a laminar or turbulent boundary layer on the localization of noise sources using an interferometry probe [9] (in cooperation with Metraflu);

- Effect of a high speed flow on an ultrasound thermometer which is to be airborne on an aircraft (in connection with the University of Paris VI).

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Other research projects are presently in progress: analysis of disturbances to acoustic wave propagation caused by thermal turbulence; measurement of turbulent pressure fields in three-dimensional and detached zones.

As we near the completion of one year's usage, it appears that the facility is flexible and likely to accommodate various types of test configurations.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Al. Bowers, E. Brian, 1973
"The anechoic flow facility aerodynamic calibration and evaluation"
Naval Ship Research and Development Center, Report SAD-48E-1942.

[2] F.C. Demetz, M.J. Casarella, 1973
"An experimental study of the intermittent properties of the boundary layer pressure field during transition on a flat plate"
Naval Ship Research and Development Center, Report 4140.

[3] J.C.A. Van Ditshuizen, G.D. Courage, R. Ross and K.J. Schultz, 1982
"Acoustic Capabilities of the German-Dutch Wind Tunnel, DNW"
Paper no. 9.5, 8th European Rotorcraft Forum, Aix-en-Provence, France.

[4] J. Bongrand, P. Lienard, 1977
"Design and construction of an anechoic chamber with an aerodynamic wind tunnel for aeroacoustic research"
9th Int. Congress Acoustics Vol. I, p. 227.

[5] J.P. Berhault, M. Sunyach, H. Arbey, G. Comte-Bellot, 1973
"Construction of an anechoic chamber covered with panels and intended for the study of aerodynamic noise"
Acustica 29(2), pp. 69-78.

[6] D. Juve, J. Bataille, G. Comte-Bellot, 1978
"Noise of coaxial jets"
J. Meca. Appliquee 2 (3), pp. 385-398.

[7] H. Arbey, M. Sunyach, G. Comte-Bellot, 1979
"Use of adjacent jets to investigate the aerodynamic sound of airfoils at moderately high Reynolds numbers"
J. Sound and Vibration 65(2), pp. 215-228.

[8] G. Robert, 1984
"Modeling and simulation of exciting field induced on a structure by a turbulent boundary layer"
Doctor-engineer thesis, ECL 84-02.

[9] Ph. Dufourcq, 1984
"Influence of a boundary layer type flow on the localization of sound sources placed in the wall"
Doctor-engineer thesis, ECL 84-11.

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