# Notes on summer work at the engine laboratory of the national research council, 29 June to 21 August, 1959

Rodkiewicz, C. M.



**Publisher's version / Version de l'éditeur:**
https://doi.org/10.4224/40003965
*Laboratory Memorandum (National Research Council Canada. Division of Mechanical Engineering. Engine Laboratory); no. NRC-ENG-14, 1959-09-16*

L.O. 13389A

FILE M6-18-1

PREPARED BY C.M. Rodkiewicz

CHECKED BY H.U. Wisniowski

# NATIONAL RESEARCH COUNCIL

## DIVISION OF MECHANICAL ENGINEERING

OTTAWA, CANADA

## LABORATORY MEMORANDUM

SECTION ENGINE LABORATORY

NO. NRC-ENG-14

PAGE 1 OF 8

COPY NO. 27

DATE 16 Sept. 1959

SECURITY CLASSIFICATION OPEN

SUBJECT NOTES ON SUMMER WORK AT THE ENGINE LABORATORY OF THE NATIONAL RESEARCH COUNCIL, 29 JUNE to 21 AUGUST, 1959.

PREPARED BY C. M. Rodkiewicz

ISSUED TO

THIS MEMORANDUM IS ISSUED TO FURNISH INFORMATION IN ADVANCE OF A REPORT. IT IS PRELIMINARY IN CHARACTER, HAS NOT RECEIVED THE CAREFUL EDITING OF A REPORT, AND IS SUBJECT TO PEVIEW.

SUMMARY

A Schlieren system was applied behind a silencing grid of a turbojet engine. It did not result in any definite additional knowledge regarding the nature of the hoot or the gas flow pattern. It is believed that the possibilities of the system were not exhausted.

Frequency of hooting was found, and its origin investigated.

A literature search was made. A theoretical solution of the problem of dissipating sound energy by water spheres suspended in the air was found. It is believed that a modified version can be applied to the case of water spray noise suppression of turbojet engine exhausts.

## TABLE OF CONTENTS



## LIST OF ILLUSTRATIONS

# NOTES ON SUMMER WORK AT THE ENGINE LABORATORY OF THE NATIONAL RESEARCH COUNCIL, 29 JUNE to 21 AUGUST, 1959

## INTRODUCTION

While working on the suppression of "hooting" noise, Mr. Wisniowski found that when a silencing grid is applied in the wake of the Orenda II turbojet engine a mass concentration is apparent at the 14" diameter just behind the grid. In order to learn more about the phenomenon, he asked the writer to investigate this region with a Schlieren system. He also requested the writer to establish the frequency of hoot and to give views concerning its origin.

This work comprised a part of the writer's summer employment with the National Research Council.

## SCHLIEREN SYSTEM

When a turbojet engine operates in an experimental cell, it develops noises which have to be suppressed. Generally speaking there are two types of suppressors: (a) stationary, and (b) non-stationary. It was found that when a stationary installation was used, of the grid type mounted in a cylindrical exhaust duct, the sound level of the exhaust jet was decreased. However, when the grid was mounted too far from the engine final nozzle, it produced a new noise called hoot. Hoot appears at higher speeds of the engine and its intensity peaks above the noise spectrum, Fig. 1. This increase was 6 db for the observed engine speed of 7500 r.p.m.

In the course of the work on suppressing hoot, it was found by the use of Wisniowski's metal tufts (no previous mention of the steel tufts was found in the technical literature) that the velocity field in the gas jet is convergent at the 14" diameter. It was this phenomenon that made Mr. Wisniowski ask the writer to build a Schlieren system and investigate the region in question.

A Schlieren unit was obtained from the High Speed Aerodynamics Laboratory and modified for local use, Fig. 2 and Fig. 3. As the source of light, an AH-4 mercury vapour lamp was used. When placed in the focus of a 9" diameter concave mirror, it produced a parallel beam of light in the desired region. On the other side of the jet was a second identical mirror which concentrated the light on the knife-edge which was constructed in conjunction with a camera. The main difficulty which had to be overcome here was the vibrations of the parts of the system. The beam of light at the test section had to be elliptical. The center of the ellipse was placed some 2" behind the grid and 7" above the center of the jet, with 9" semi-major and 6" semi-minor axis.

The visual observations and the photographs showed, as could be expected, that this subsonic region is of very turbulent nature, Fig. 4. Relative density gradients within the jet were found to be of small magnitude and of no definite steady pattern. The changes were rather fast in succession. It seemed that there would be at times some kind of to-and-fro action close to the 14" diameter. A double series of vortices, as something of similar nature, would suggest itself (7).

In conclusion, the Schlieren system did not produce any definite additional knowledge with regard to the nature of the hoot or the gas flow pattern. However, before the system is rejected it should be pointed out that the flow field dealt with was non-steady and in particular three-dimensional. Perhaps the smoke technique, in conjunction with the Schlieren system, would shed some additional light on the 14" diameter phenomenon.

Schlieren pictures were also obtained with a 14" diameter partially perforated cylinder placed concentric with the turbojet engine axis and behind the grid. One could no longer detect the to-and-fro action in the visible portion of the jet. Flow was in streaks, more or less parallel to the cylinder wall, and the intensity of hoot was decreased. It could be mentioned that P.N. Kubanskii (2), in his effort to couple the thermal and acoustic effects, used the shadowgraph method. He found that when a hot cylinder is placed in the air at rest, and when the sound field is superimposed, it produces cells of circulating air.

## THE NATURE OF HOOT

It was felt that it would be convenient to find the frequency of hoot and to try to see if parts of the rig installation are not responsible for it. For this purpose the spectrum of sound was obtained, Fig. 1.

A Bruel and Kjaer Type 2110 Audio Frequency Spectrometer was used, in conjunction with Type 2304 Level Recorder and Type 1014 Beat Frequency Oscillator. The turbojet engine was operated at 7500 r.p.m. and 7000 r.p.m. The exhaust gas passed through an 8-spoke grid welded in a 40" diameter ring which was mounted in the cell's 48" diameter outlet duct. No water spray was used. It was found that the hooting frequency at 7500 r.p.m. was somewhere between 400 cps and 630 cps, but close to 500 cps. The hooting frequency at 7000 r.p.m. was somewhere between 630 cps and 1000 cps, but close to 800 cps. The intensity received by a microphone, placed on the third floor balcony*, was indicated as 101 db at 7500 r.p.m. and 90.5 db at 7000 r.p.m. The over-all sound level was 107.5 db at 7500 r.p.m. and 102.5 db at 7000 r.p.m.

Due to limitations of the instruments, at first only approximate frequency values of hoot could be obtained. Later an Ampex Model 620 Amplifier-Speaker was used in conjunction with the 1014 Beat Frequency Oscillator. The sound frequency emitted by the speaker could be varied and compared by ear with that of hooting. It was found that at 7500 r.p.m., hoot frequency was 500 cps, and that at 7000 r.p.m. it was 750 cps.

The origin of hoot is still under examination. It appears from the experiments that the turbojet engine itself is not directly responsible for the hoot. It is also evident that when a silencing grid located in a cylindrical or square frame is placed close to the tailpipe there is no hoot; but at the same time it can affect the thrust and tailpipe temperature of the engine (both increase). To avoid it, the grid has to be moved downstream past a critical point where the hoot starts to develop. It would therefore be reasonable to assume that hoot is a resonant phenomenon born within the installation in the wake of the turbojet engine.

A few simple calculations were made with regard to 500 and 750 cps frequencies. The indication is that the 48" diameter outlet duct has at 7500 r.p.m. one of the harmonics of its natural transverse vibration frequency close to 500 cps, and at 7000 r.p.m. close to 750 cps. The calculations were a very rough approximation, as errors may be expected in the assumed temperatures while evaluating the velocity of sound in the gas column.

To prove the above implication, the writer would suggest reducing the 500 cps frequency to the still air velocity of sound. A signal of that frequency could be fed flush with the duct wall to prove that there is no resonance. On the other hand, one could split the duct's area into, say, four equal diameter pipes. This may result in a new frequency of hoot which could be pre-calculated. Should this be so, one could find a theoretical diameter of the pipe which, if practical, would shift the hoot frequency out of the threshold of hearing.

## WATER SPRAY NOISE SUPPRESSION

Mr. Wisniowski developed the technique of reducing the

---

* 26 feet below the outlet of the vertical exhaust stack, and about 13 feet from its vertical axis.

sound energy level by creating water spray downstream of the silencing grid. It was necessary to introduce a mathematical theory in support of these experiments. The writer made a literature search, as listed below, and found that the partial theoretical solution of the problem was made by P.S. Epstein and R.R. Carhart (4). The paper develops a theory of sound absorption by fluid spheres embedded in a fluid medium, in particular, water particles suspended in the air. A droplet is selected and its absorption is determined. The total absorption is obtained by summing up the individual absorptions of the droplets. The formula deduced for the sound attenuation consists of two terms designated as the coefficient of viscous attenuation and the coefficient of thermal attenuation. The theory is favourably compared with Knudsen's (16) data on absorption of sound energy in artificially produced fog. The comparison was possible because the analysis of drop size was made.

## LITERATURE AND REFERENCES

| | | |
|---|---|---|
| 1 | Callaghan E.E.<br>Coles W.D. | Far Noise Field of Air Jets and Jet Engines. Natl. Advisory Comm. Aeronaut. Rept. 1329, 1957. |
| 2 | Kubanskii | Flow Around a Heated Solid Body Located in a Sound Field. Zhur. Tekh. Fiz. 22, 585 (1952). |
| 3 | Lassiter L.W.<br>Hubbard H.H. | Experimental Studies of Noise from Subsonic Jets in Still Air. Natl. Advisory Comm. Aeronaut. Note 2757, 1952. |
| 4 | Epstein P.S.<br>Carhart R.R. | The Absorption of Sound in Suspensions and Emulsions. The Jour. of Acoust. Soc. of Am., Vol. 25, No. 3, 553, 1953. |
| 5 | Rolling V.G. | Effect of Jet Temperature on Jet Noise Generation. Natl. Advisory Comm. Aeronaut. Tech. Note 4217, 1958. |
| 6 | Morse R.W. | Acoustic Propagation in Granular Media. The Jour. of Acoust. Soc. of Am., Vol. 24, No. 6, 1952. |
| 7 | Wood A.B. | A Text-book of Sound. G. Bell & Sons Ltd., p. 362, 1955. |

| | | |
|---|---|---|
| 8 | Player E.S. | Meteorological Conditions and Sound Transmission. Jour. of the Royal Meteorological Society, Vol. 52, No. 220, 1926. |
| 9 | Callaghan E.E.<br>Sanders N.D.<br>North W.J. | Recent NACA Investigation of Noise-Reduction Devices for Full-Scale Engines. Aeronautical Engineering Review, June 1955. |
| 10 | Tyler J.M.<br>Perry E.C. | Jet Noise. SAE Transactions, Vol. 63, 1955. |
| 11 | Fitzpatrick H.M.<br>Lee R. | Measurement of Noise Radiated by Subsonic Air Jets. David Taylor Model Basin Rept. 835 (1952). |
| 12 | Milne E.A. | Sound Waves in the Atmosphere. Philosoph. Magazine & Jour. of Science, Vol. XLII, 6 series, 1921. |
| 13 | Tucker W.S. | The Hot Wire Microphone and its Application to Problems of Sound. Jour. of the Royal Society of Arts, Vol. 71, No. 3659, Jan., 1923. |
| 14 | King L.V. | On the Propagation of Sound in the Free Atmosphere and the Acoustic Efficiency of Fog-Signals Machinery. Royal Society, Phil. Trans., p. 219, 1919. |
| 15 | Greatrex F.B. | Jet Noise. The Engineer, July 1, 8 and 15, 1955. |
| 16 | Knudsen V.O.<br>Wilson G.B.<br>Anderson N.S. | Attenuation of Audible Sound in Fog and Smoke. The Jour. of Acoust. Soc. of Am. 20, 849, 1948. |

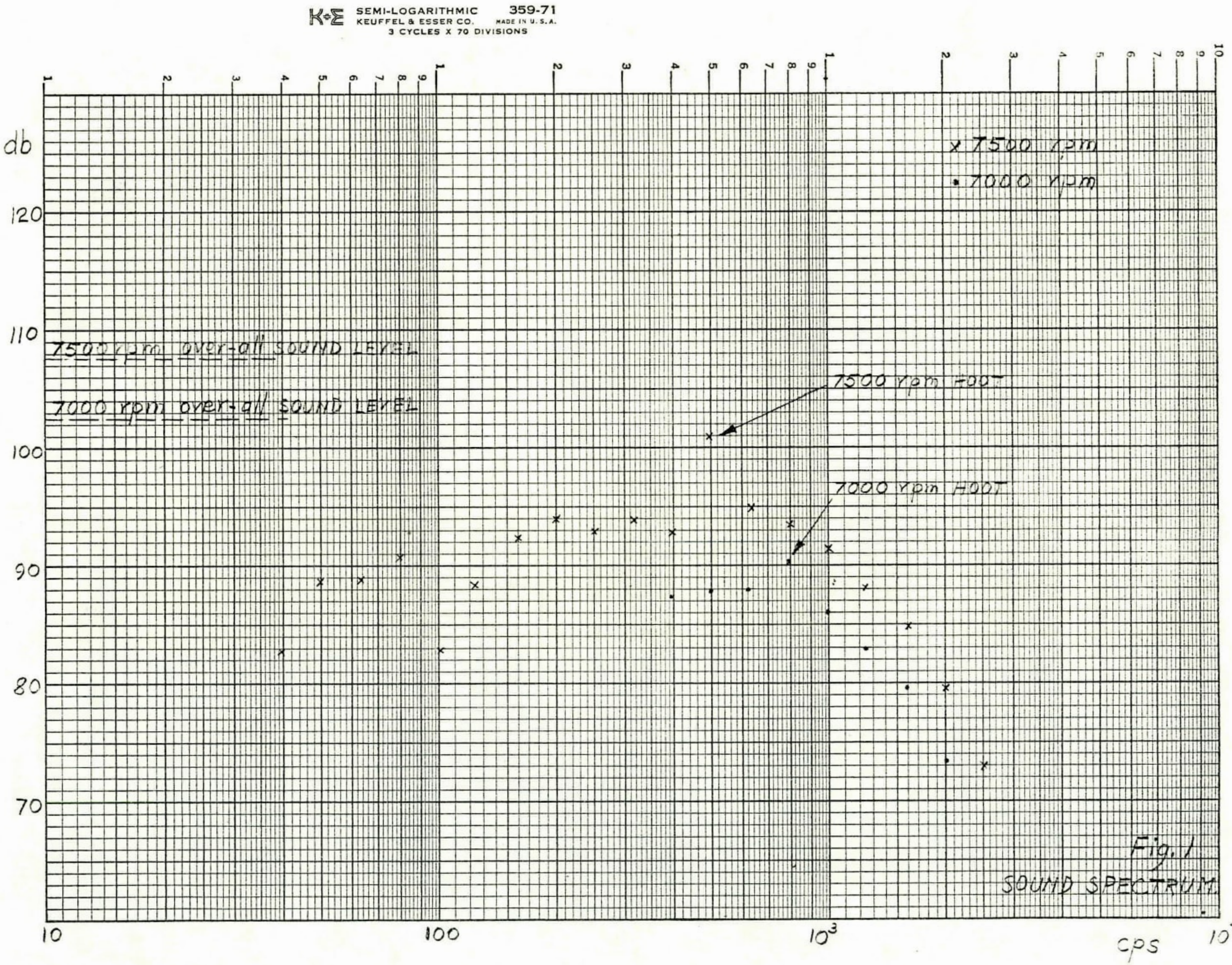
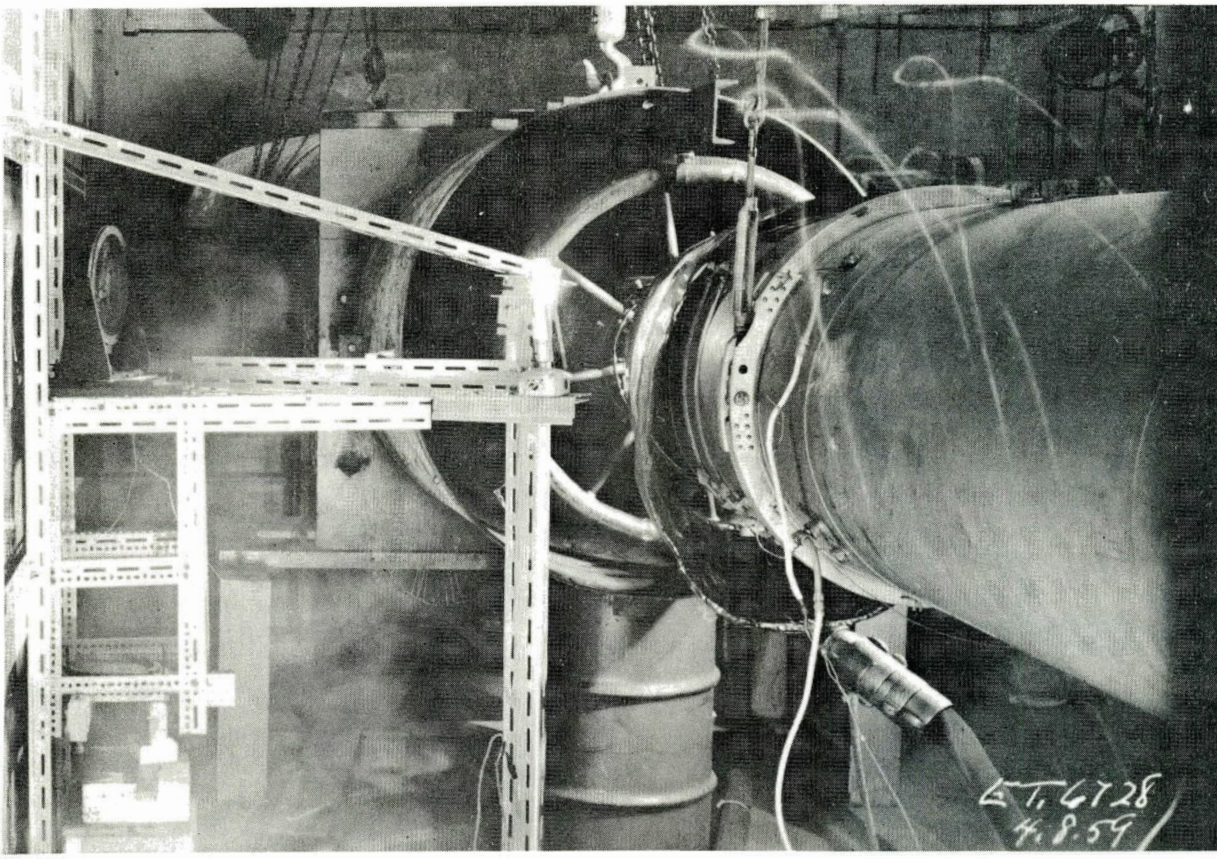


Fig. 1
SOUND SPECTRUM

FIG. 2

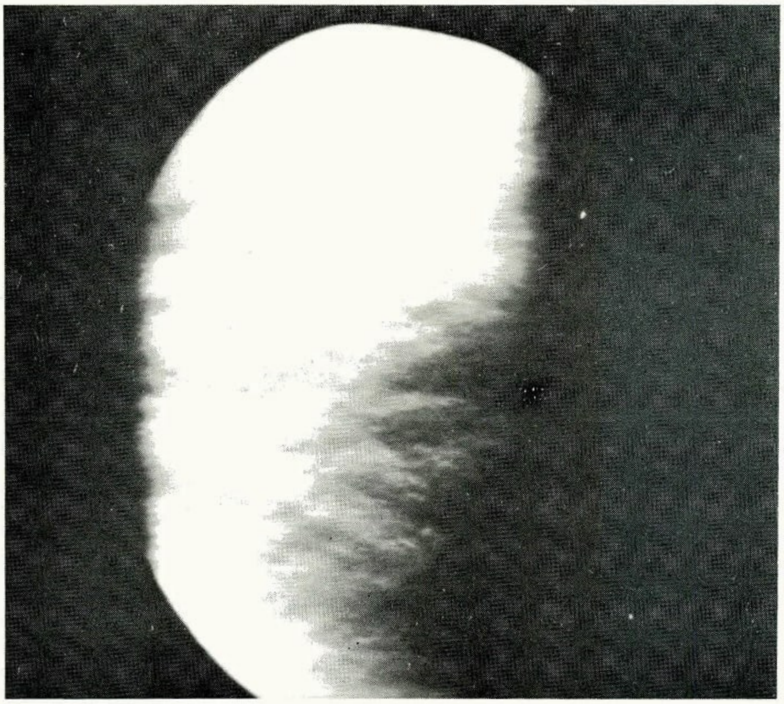



SCHLIEREN SYSTEM
SOURCE OF LIGHT AND FIRST MIRROR

FIG. 3


SCHLIEREN SYSTEM
SECOND MIRROR, KNIFE-EDGE AND THE CAMERA

FIG. 4



A GAS FLOW SCHLIEREN PHOTOGRAPH
(FLOW DIRECTION: FROM LEFT TO RIGHT)