The Evolution of Modulated Wavetrains into Turbulent Spots

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Experiments are being carried out to study the process by which the almost periodic disturbance waves generated naturally by the freestream evolve into turbulence. The boundary layer on a flat plate has been used for this study. The novelty of the approach is in the form of artificial excitation that is used.

Although we know, through many experimental and theoretical studies, something about the development of regular Tollmien-Schlichting waves, we know very little about the evolution of naturally excited waves. Indeed, if one carries out an experiment on a plate in a wind tunnel without any controlled excitation, it appears that bursts of turbulence appear spontaneously and one has to look very hard for any wavy precursor.

In this work the flow is excited artificially by deterministic white noise. The weak T-S wave created develops down stream, becomes nonlinear and blows up locally into a highly distorted flow. These large local distortions of the mean flow allow very high frequency disturbances to grow and form into small turbulent spots. The spots arise from the excitation, and if the same noise sequence is repeated a spot will form at the same position and time instant relative to the excitation. Of course the details of the high frequency oscillations within the spot will inevitably vary from realisation to realisation, but the overall structure is maintained. The probe may be moved around so that the structure and development of these artificially excited spots can be measured. Also the nonlinear wavy flow that causes the spot can be examined prior to breakdown.

Wavelet transform and SVD (Singular Value Decomposition) have been used as tools to examine different regions of the signals of interest. In particular these techniques enable the fine structure of the breakdown to be filtered out from the signal.

Recent work on the use of a dynamical system approach to spatial chaos will also be discussed.

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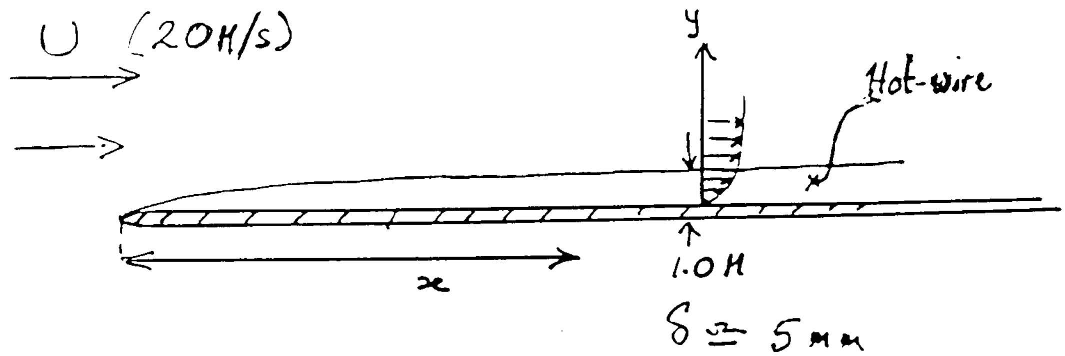
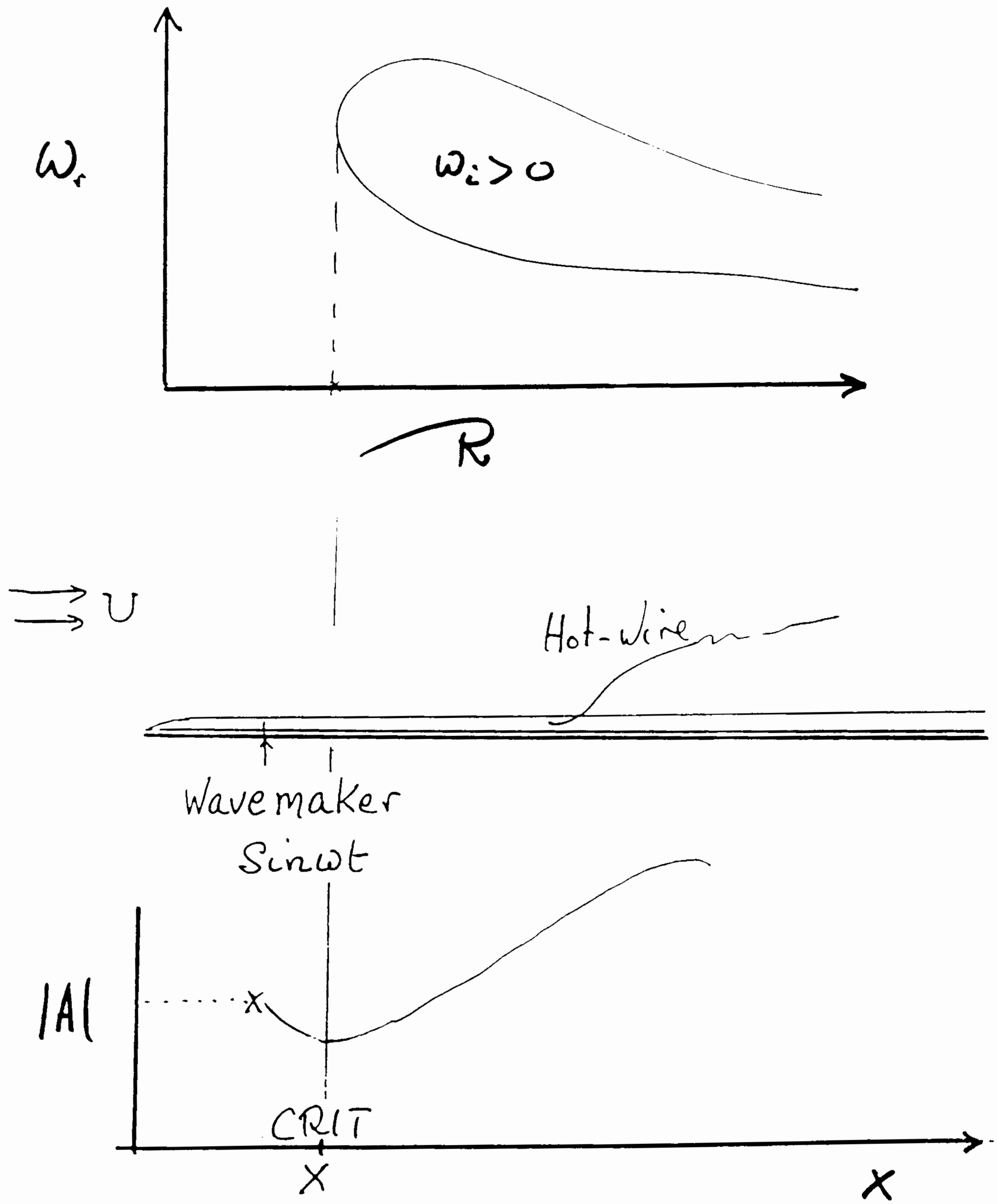
Transition from laminar to turbulent flow in the boundary layer of a plate

British Maritime Technology
[BMT]

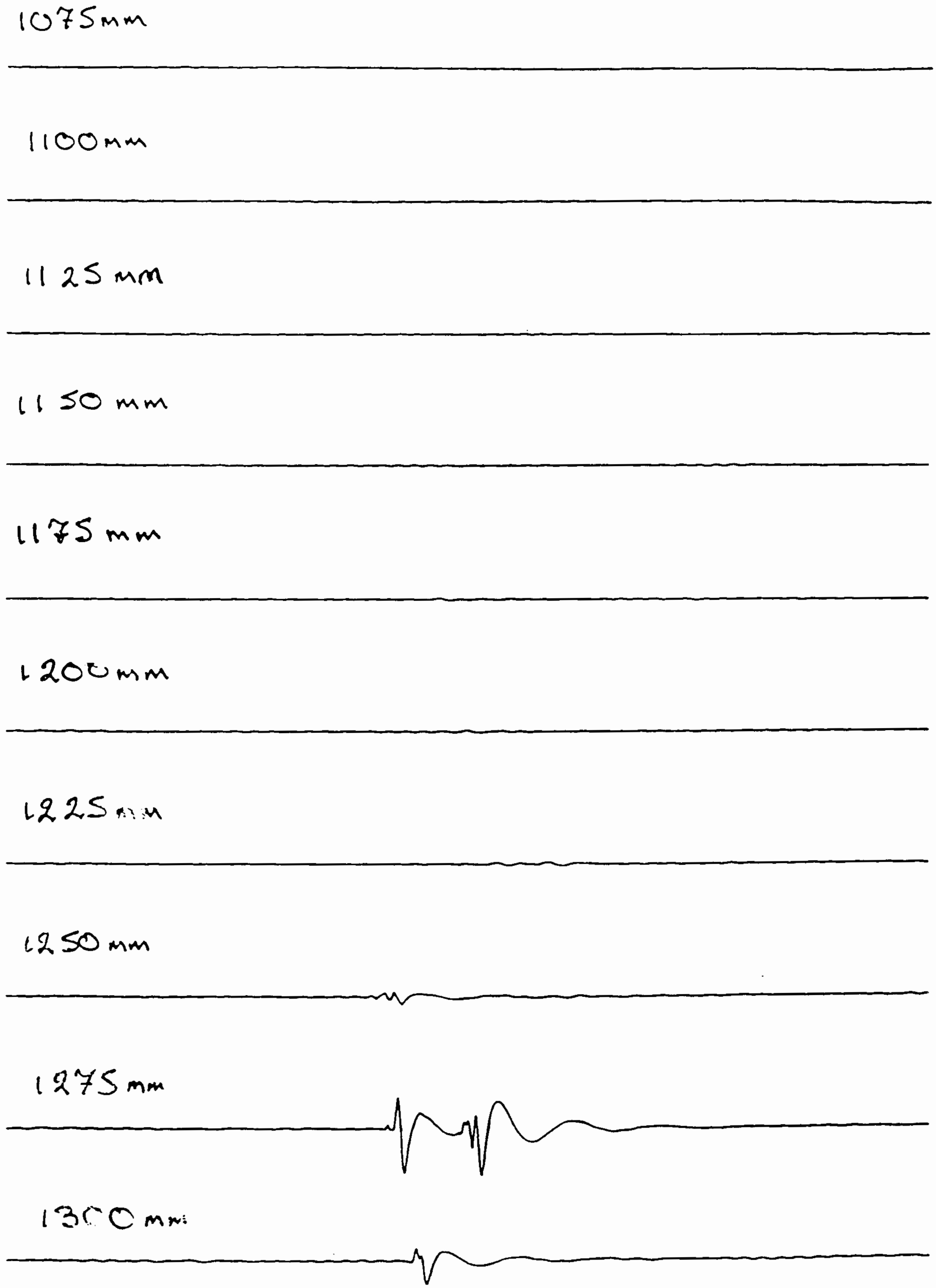
A typical wind tunnel experiment.

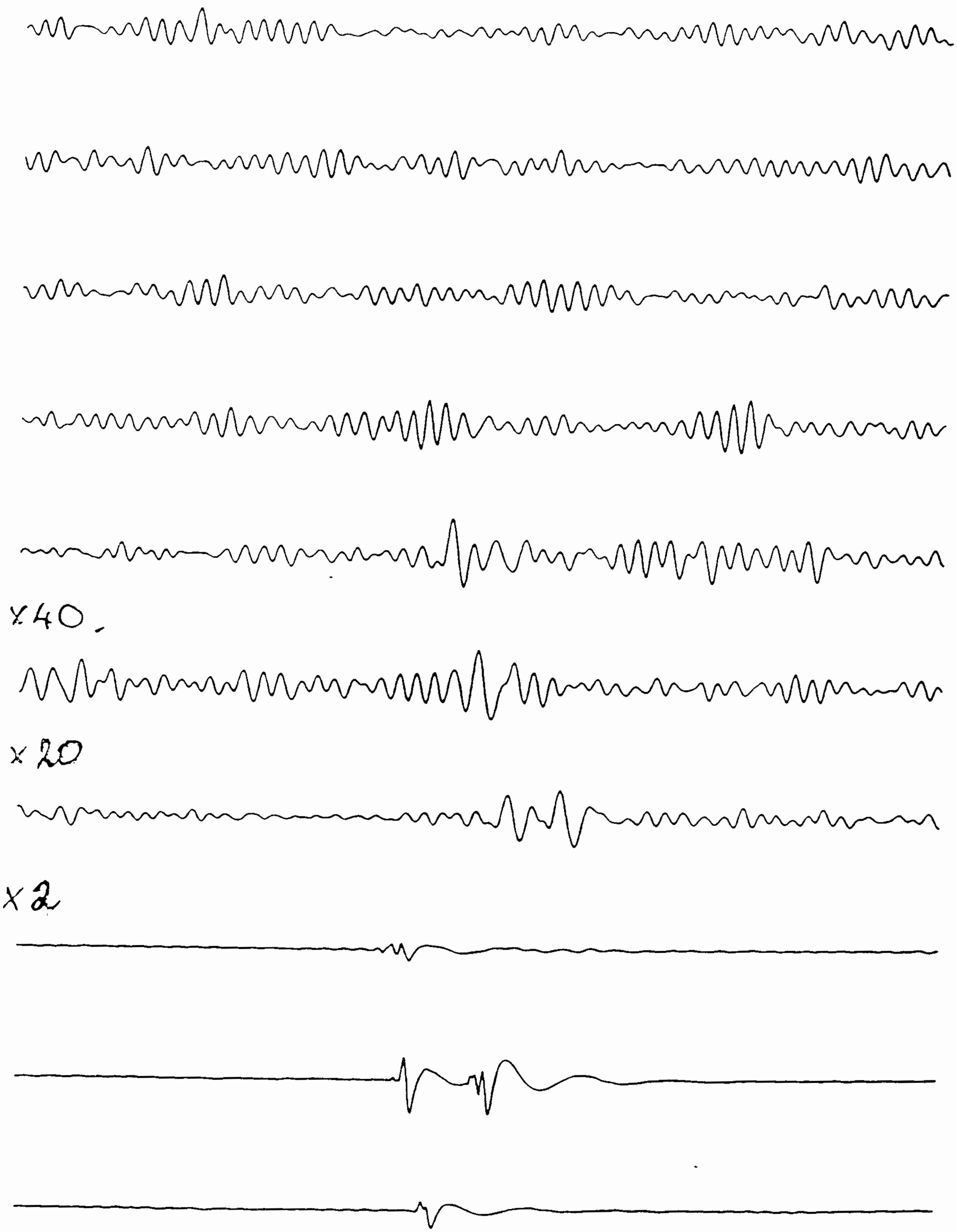


Typical fluctuations in the oncoming flow $\sqrt{\overline{u^2}} < 0.01\% \, U_\infty$


ω_r
ω_i > 0
R
U
Hot-wire
Wavemaker
Sinωt
|A|
CRIT
X
x

3/

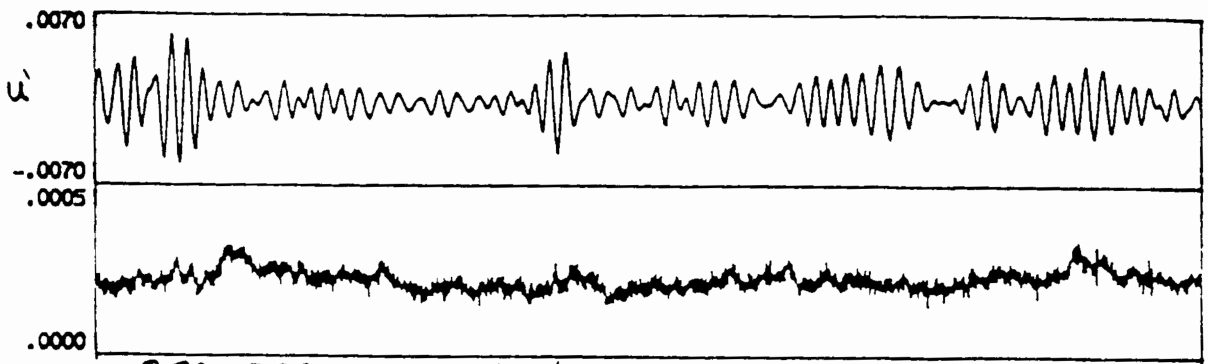

1075mm
1100mm
1125 mm
1150 mm
1175 mm
1200mm
1225mm
1250 mm
1275 mm
1300 mm


x40.
x20
x2

5/

X (mm) = 400.00

0·04 % FREE STREAM

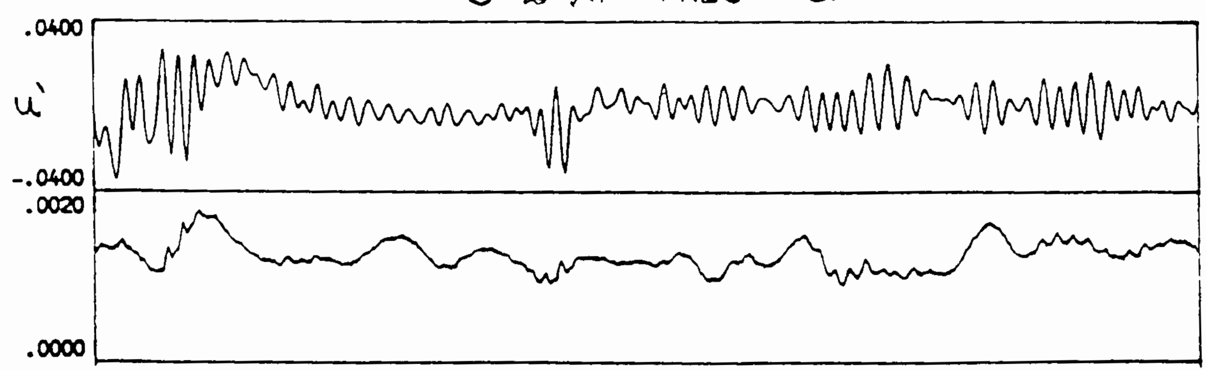


STANDARD DEVIATION

RATIO = 7 %

ETA = 4.24

0·2 % FREE STREAM



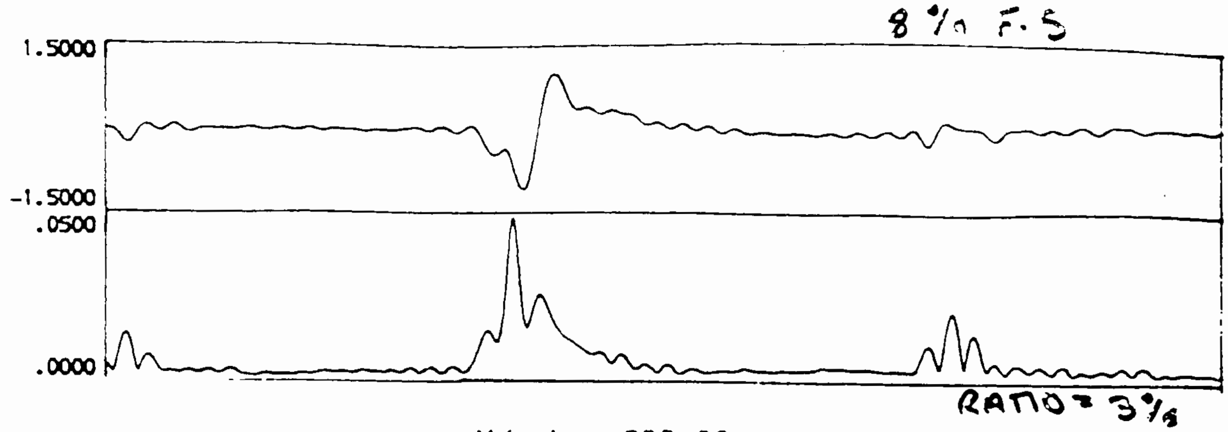
STANDARD DEVIATION.

RATIO = 5 %

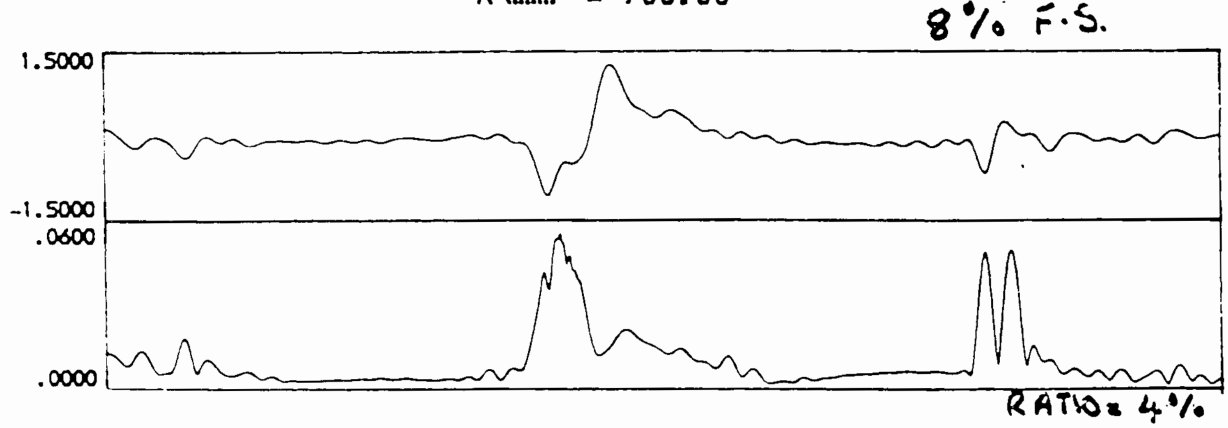
ETA = 0.75

- NOTE DIFFERENT SCALES.

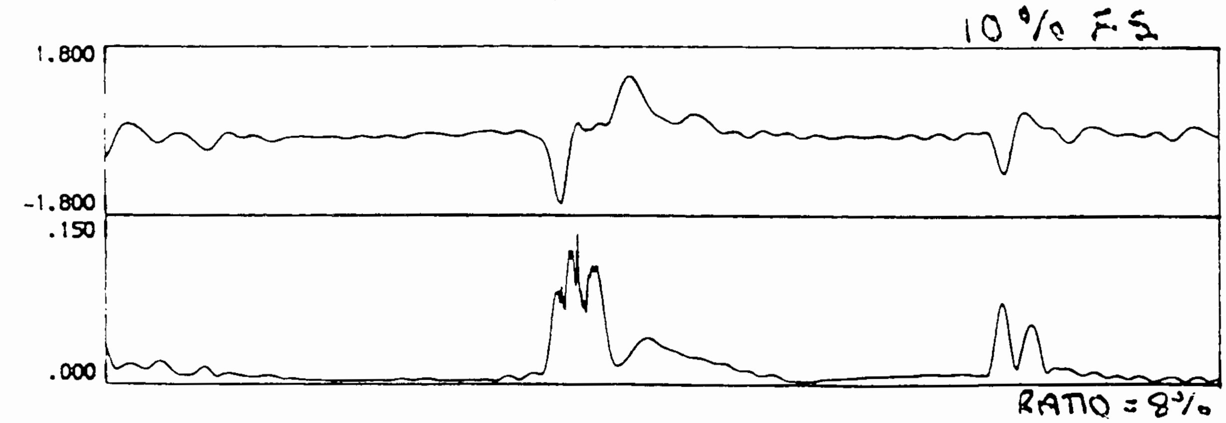
ETA = 0.75



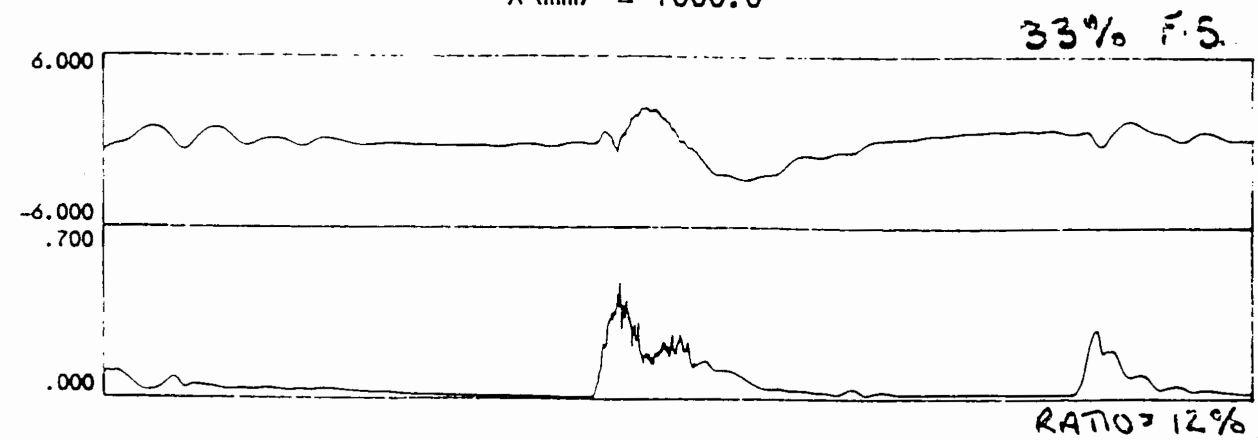
X (mm) = 900.00



X (mm) = 975.00



X (mm) = 1000.0



X (mm) = 1100.0

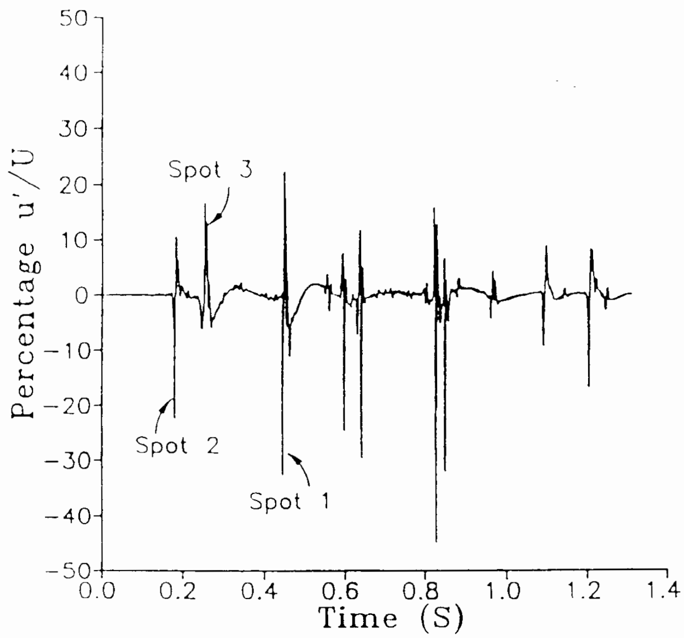


Figure 5

Fluctuating streamwise velocity signal showing incipient spots, X = 1.1 m, Z = 0.02 m.

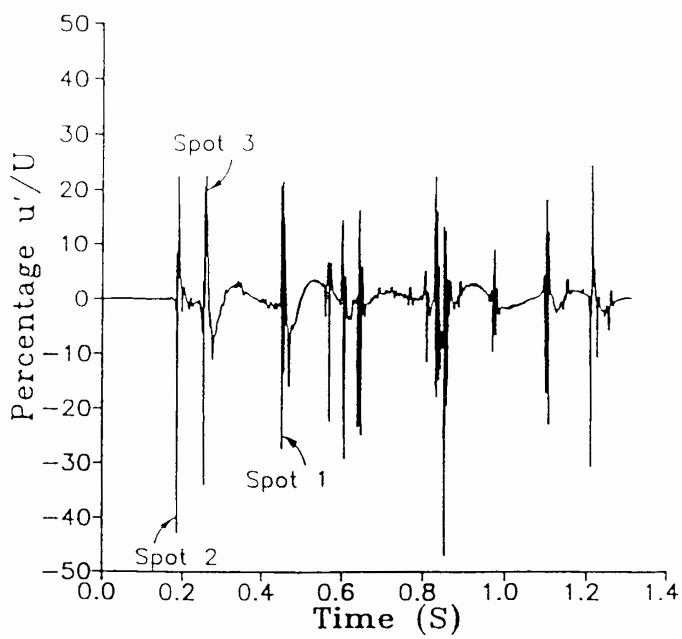


Figure 6

Fluctuating streamwise velocity signal showing incipient spots, X = 1.15 m, Z = 0.02 m.

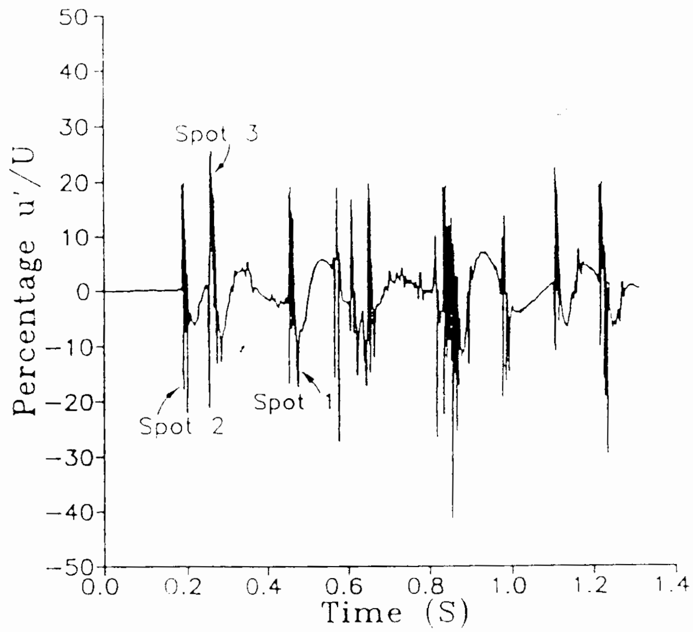


Figure 7

Fluctuating streamwise velocity signal showing incipient spots, X = 1.20 m, Z = 0.02 m.

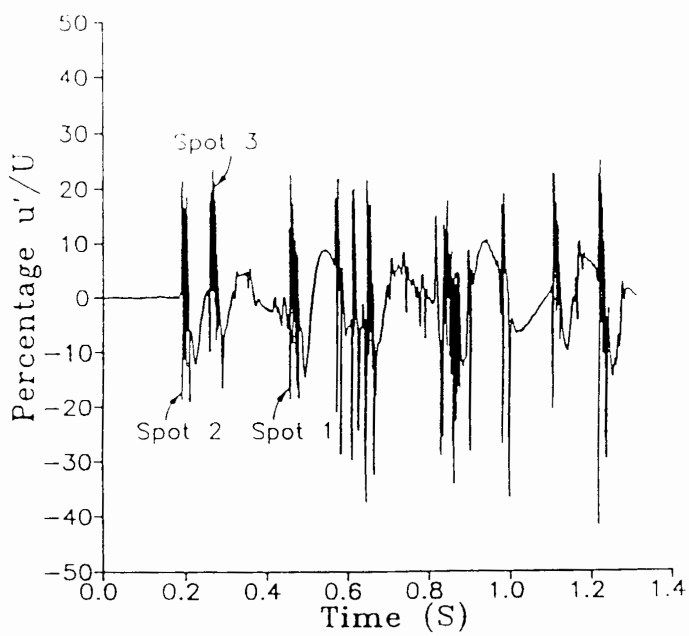
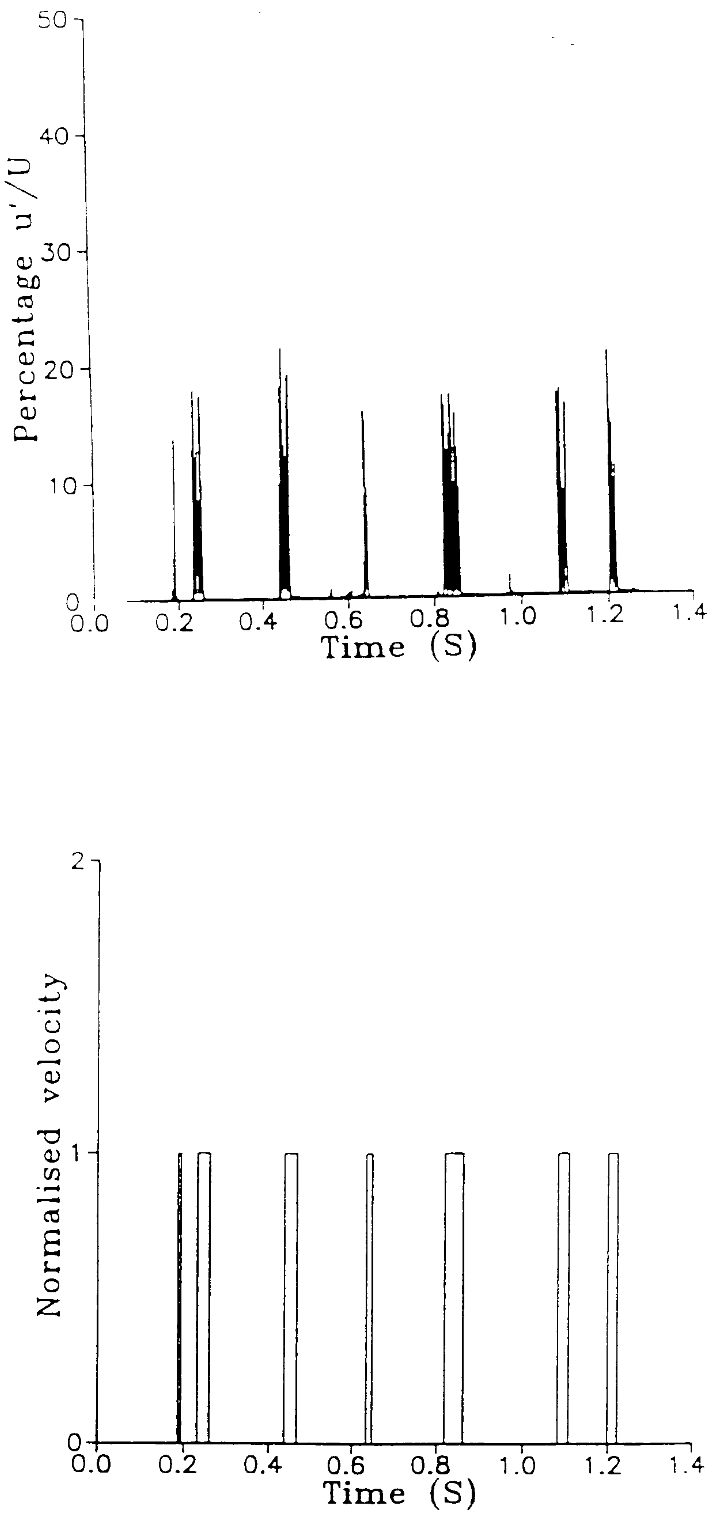


Figure 8

Fluctuating streamwise velocity signal showing incipient spots, X = 1.25 m, Z = 0.02 m.



The processed signal from which the intermittency is estimated