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N° d'ordre 610

HOYEZ-DELALIAUX Marie-Claire



20 Novembre 1990

FIGURES

SCD LILLE 1



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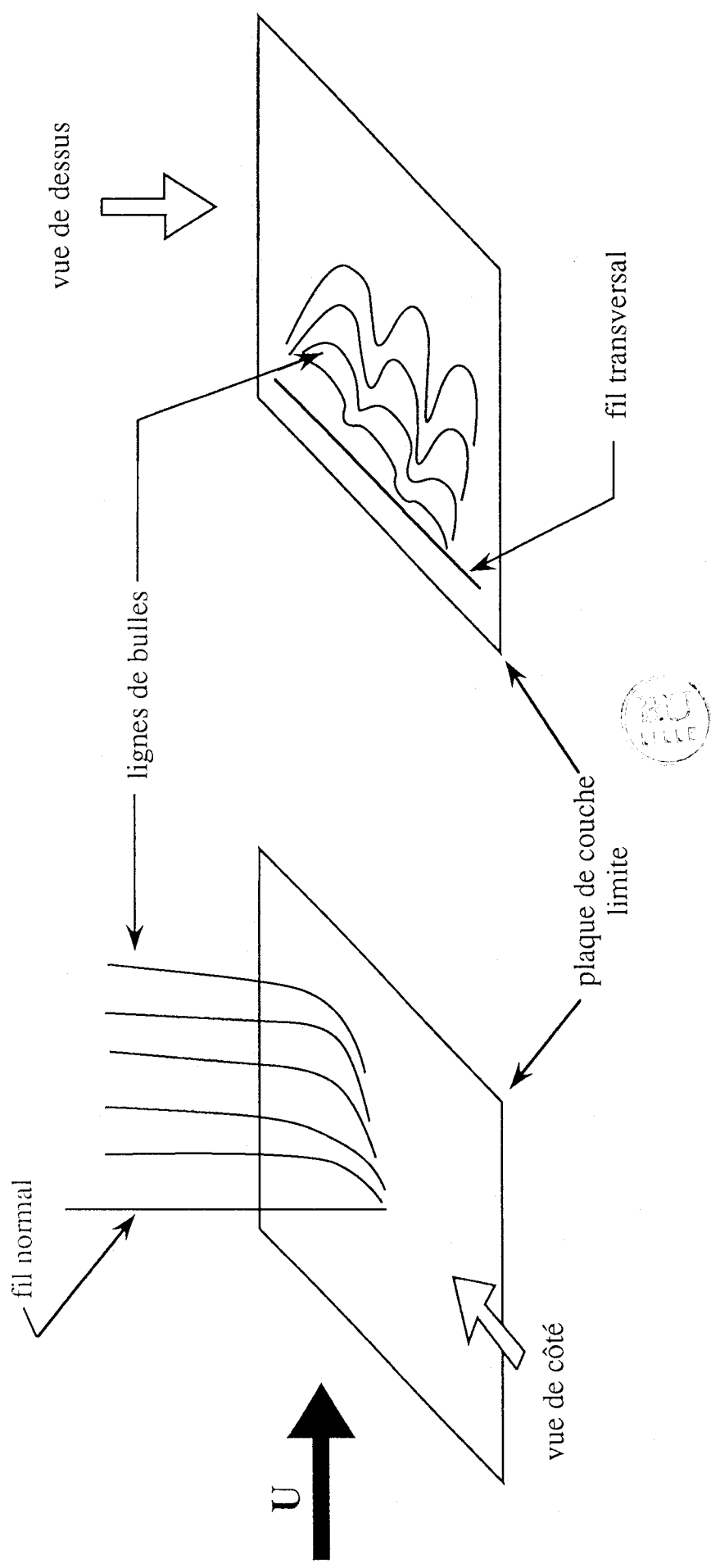
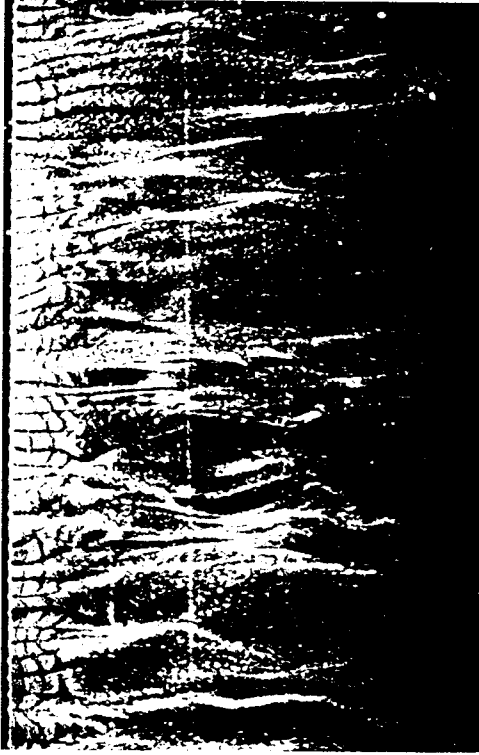
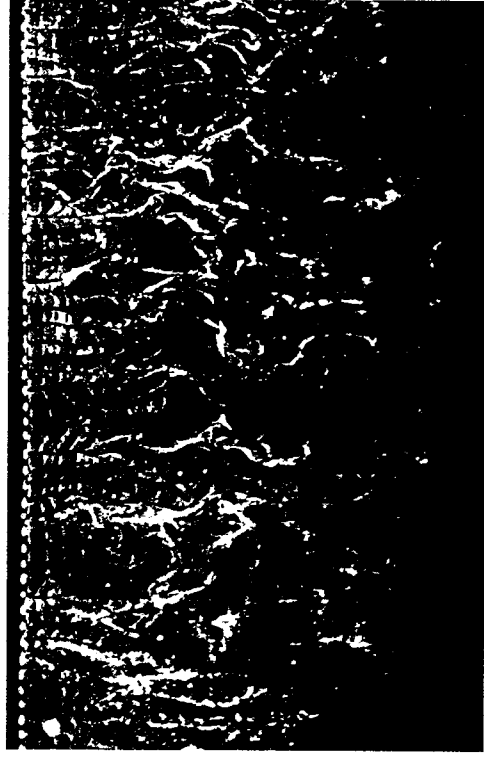


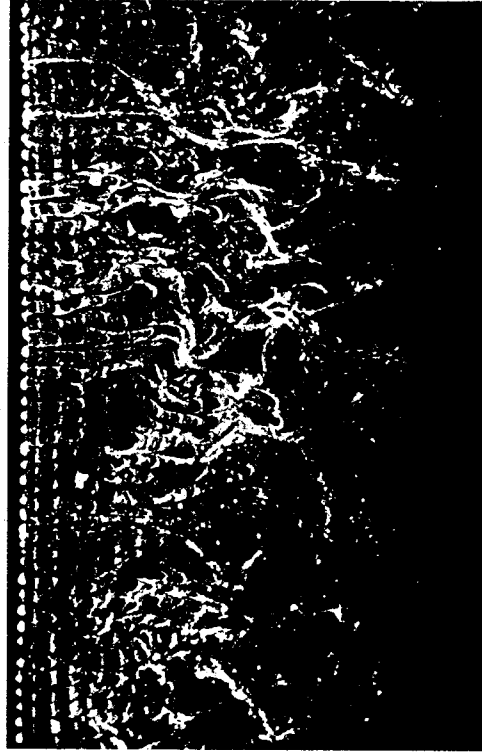
Figure 1-1 Technique de visualisation par bulles d'hydrogène



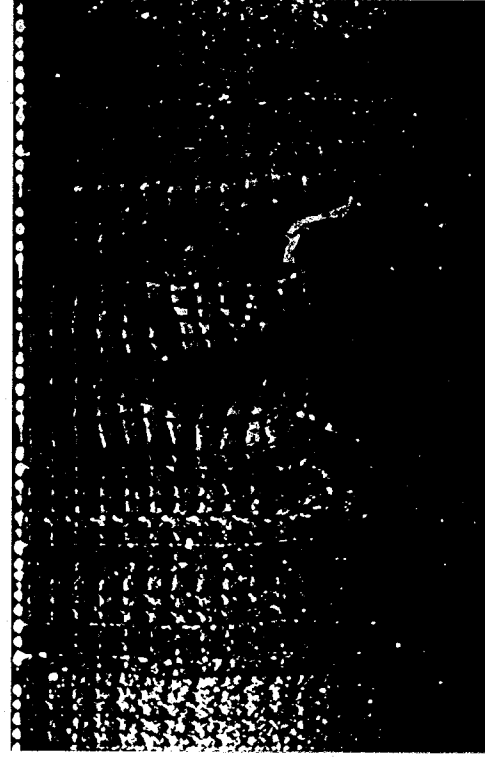
$y^+ = 2.7$



$y^+ = 38$



$y^+ = 101$



$y^+ = 507$



Figure 1-2 Visualisations de la structure de la couche limite turbulente de plaque plane par bulles d'hydrogène [5]

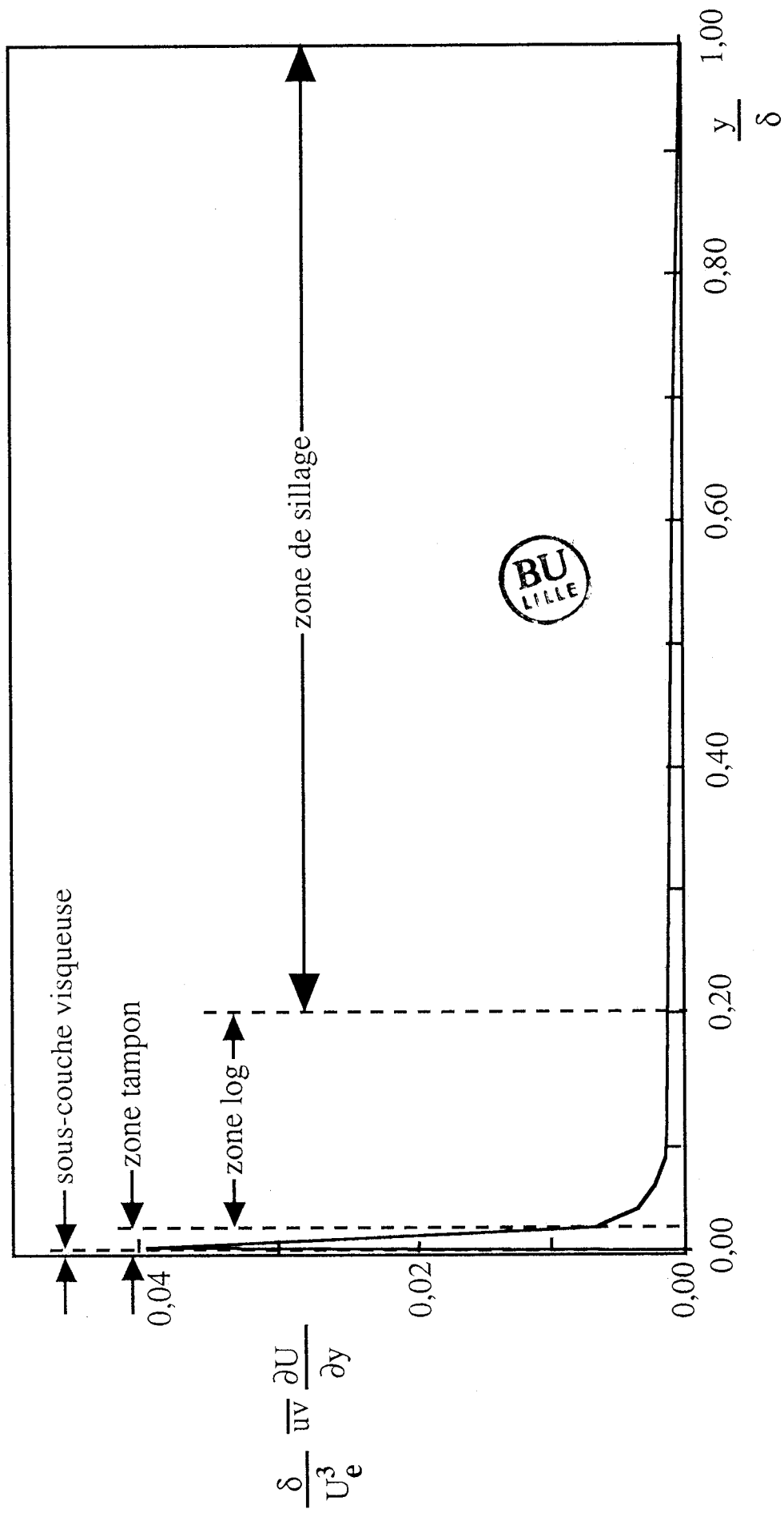


Figure 1-3 Taux de production d'énergie turbulente par unité de volume dans une couche limite turbulente [7]

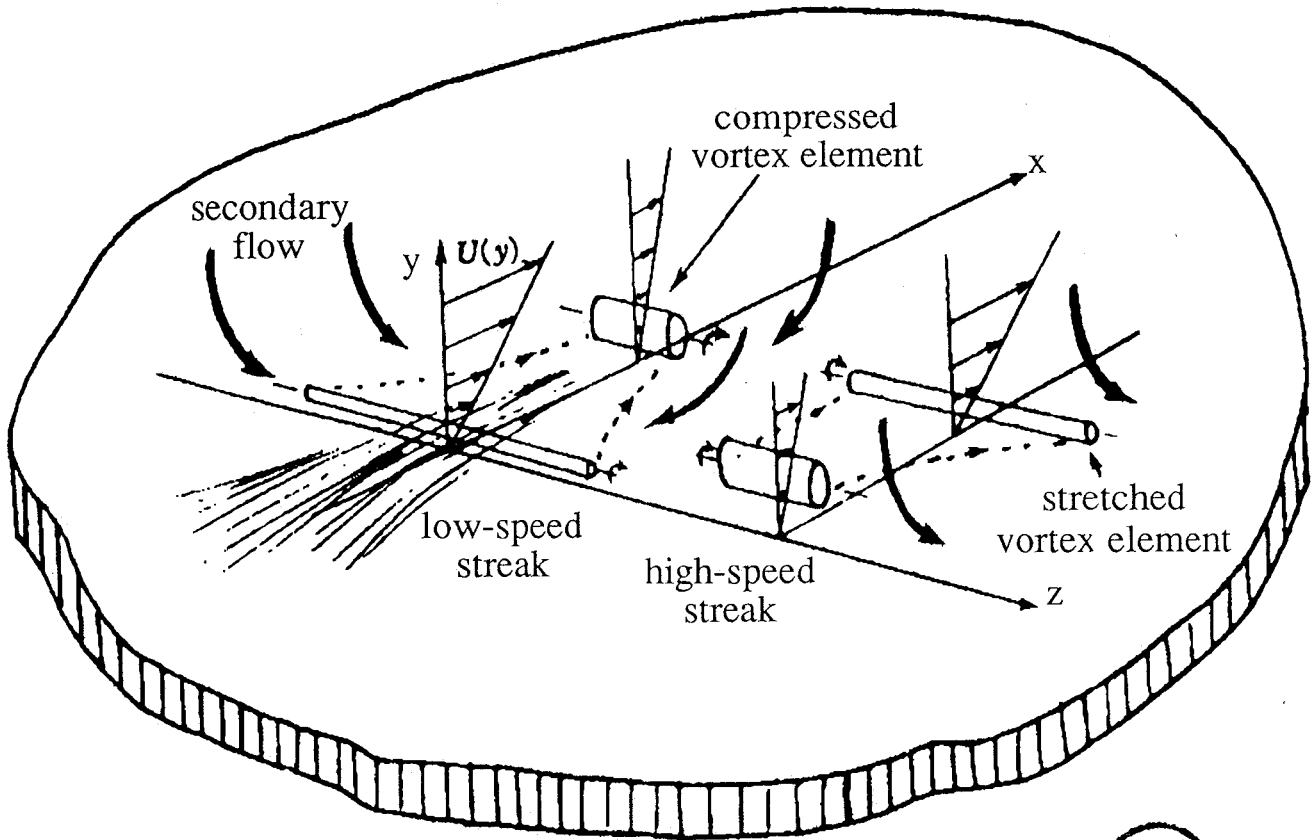


Figure 1-4 Formation des *streaks* [5]

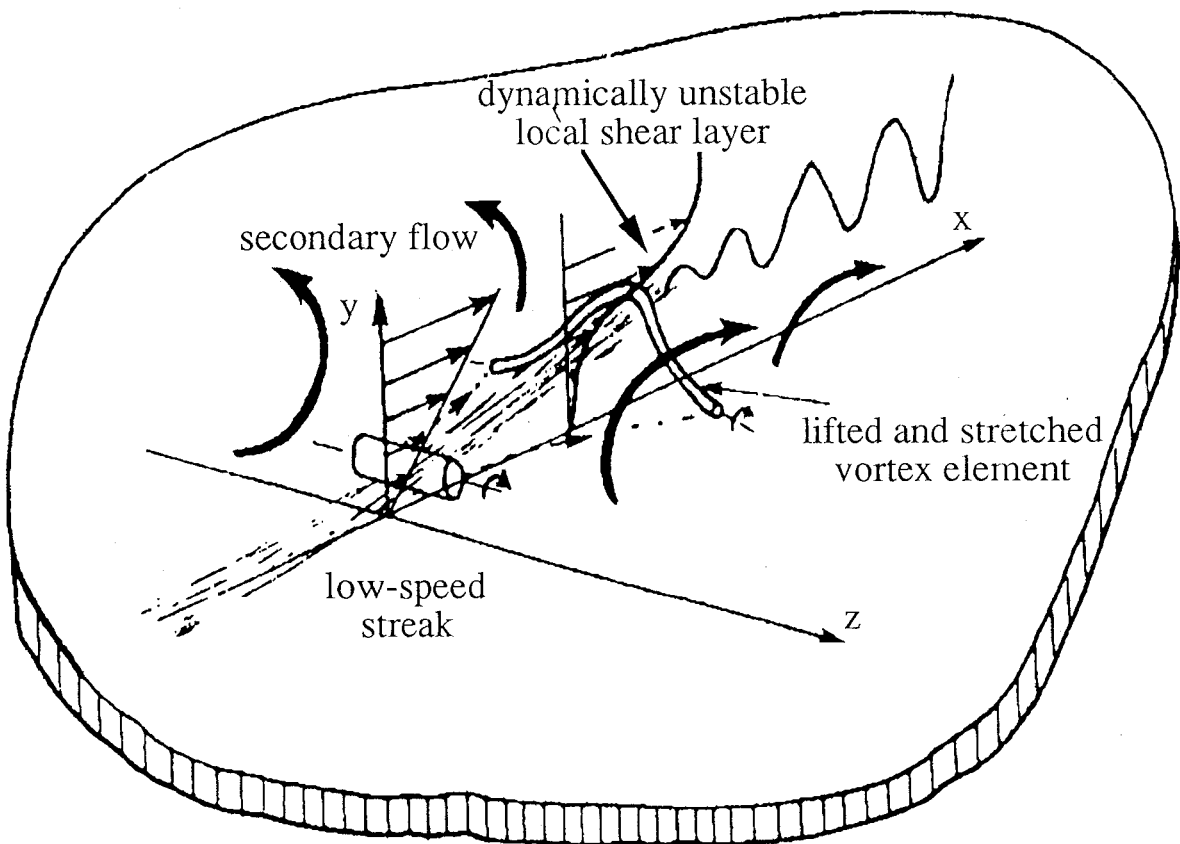
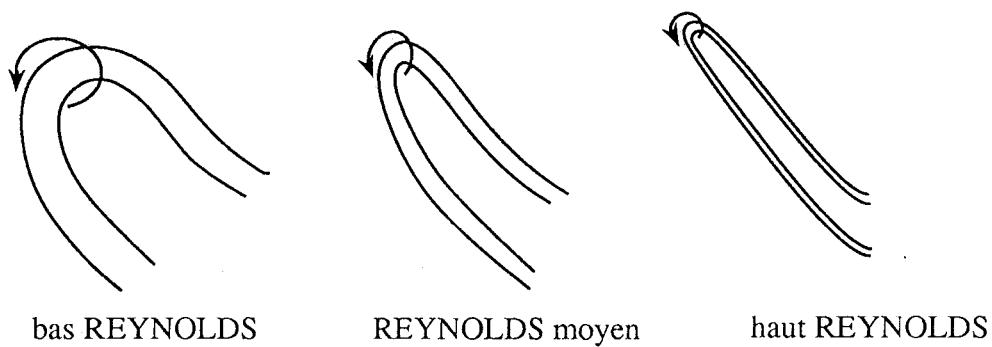
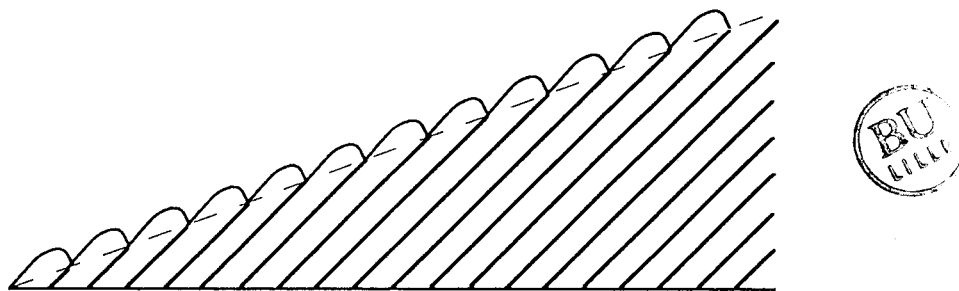


Figure 1-5 Mécanisme d'éjection [5]



(a) Influence du nombre de REYNOLDS sur les structures en épingle à cheveux



(b) Interface à 20° formée par les structures en épingle à cheveux inclinées à 45° par rapport à la paroi

Figure 1-6 Structures en épingle à cheveux [23]

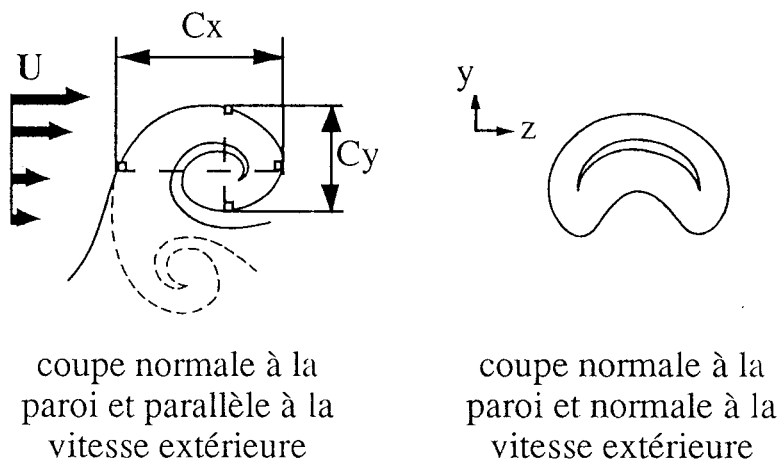


Figure 1-7 Forme générale d'un tourbillon typique de FALCO

(a) FALCO [30]

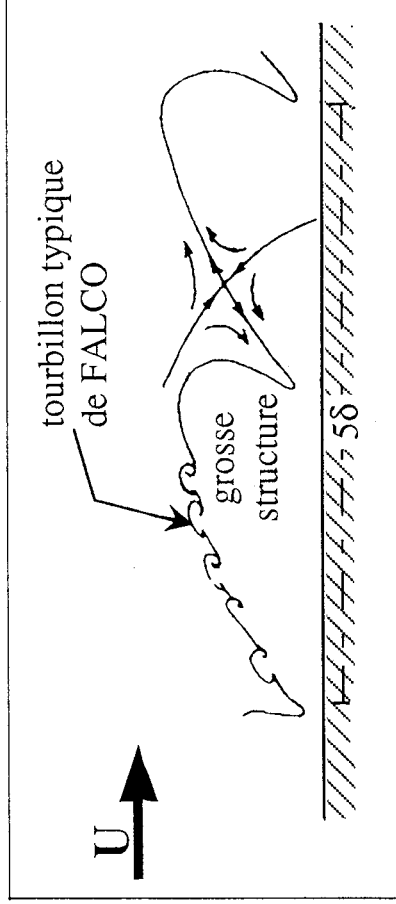
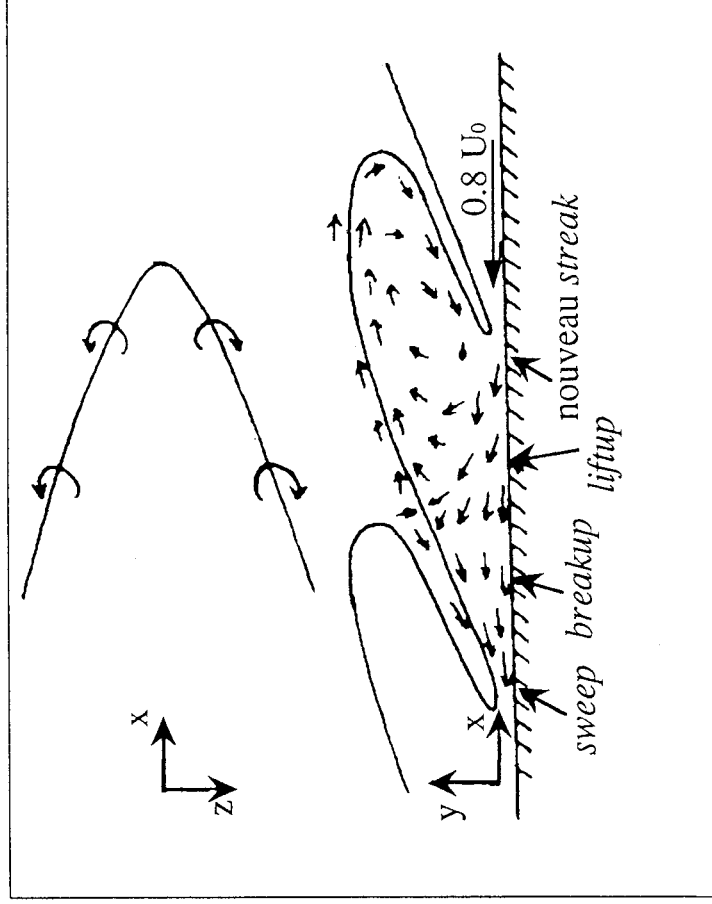
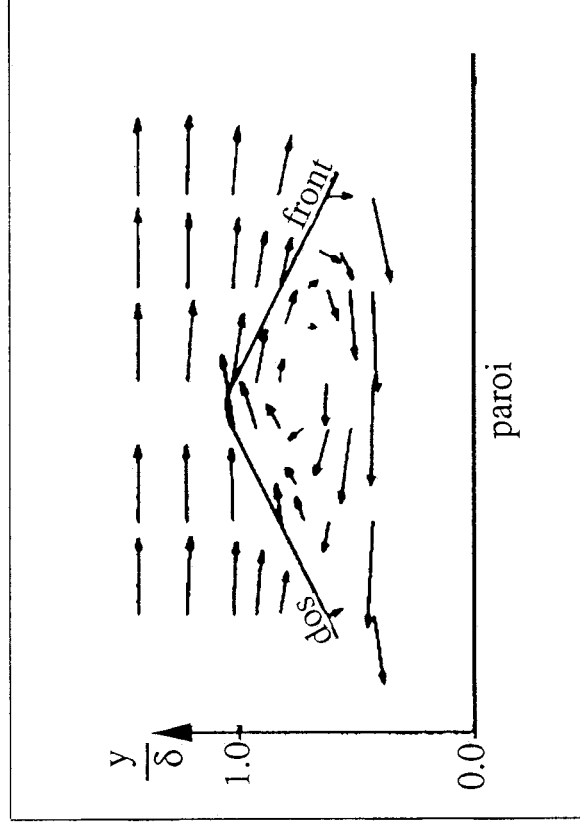


Figure 1-8 Modèles de la structure externe d'une couche limite turbulente



(b) BROWN - THOMAS [28]



(c) BLACKWELDER - KOVASNAY [29]

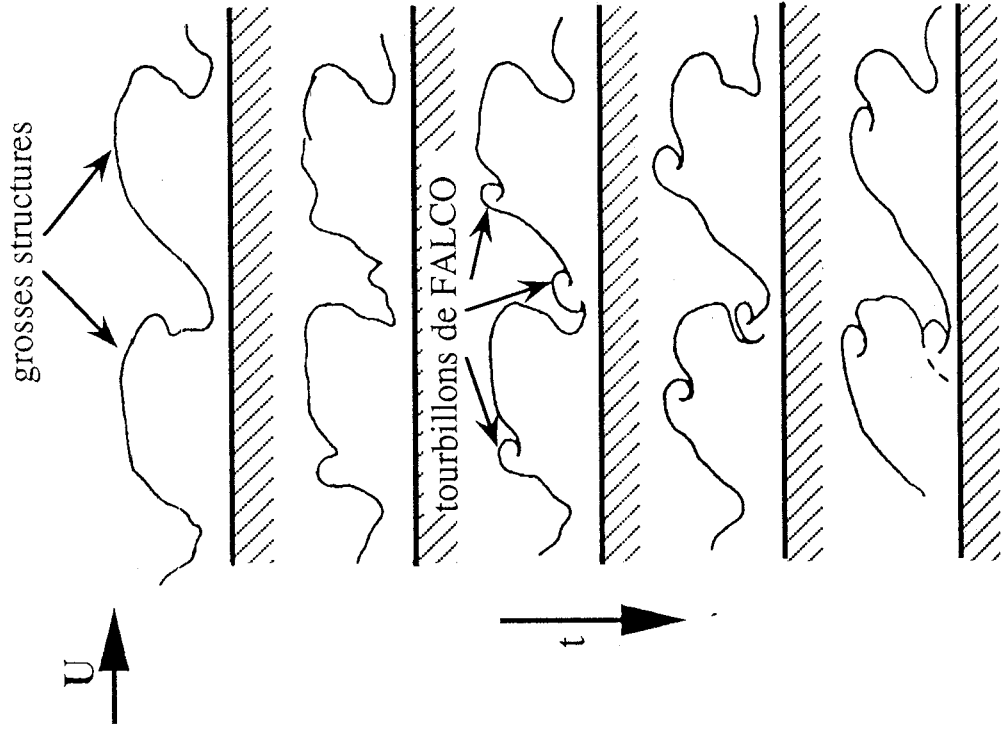


Figure 1-9 Evolution des tourbillons typiques de FALCO sur les grosses structures [30]

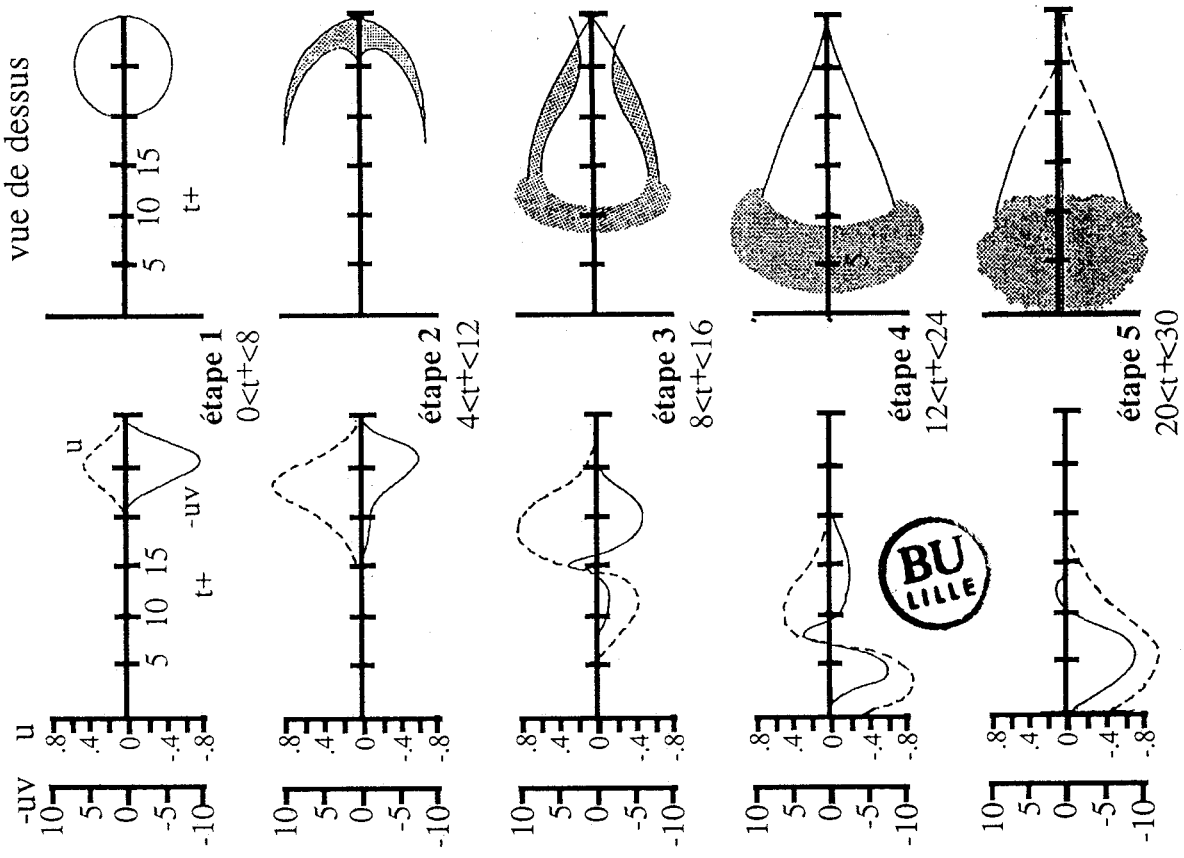


Figure 1-10 Evolution d'une pocket [32] ($y^+ = 16$)

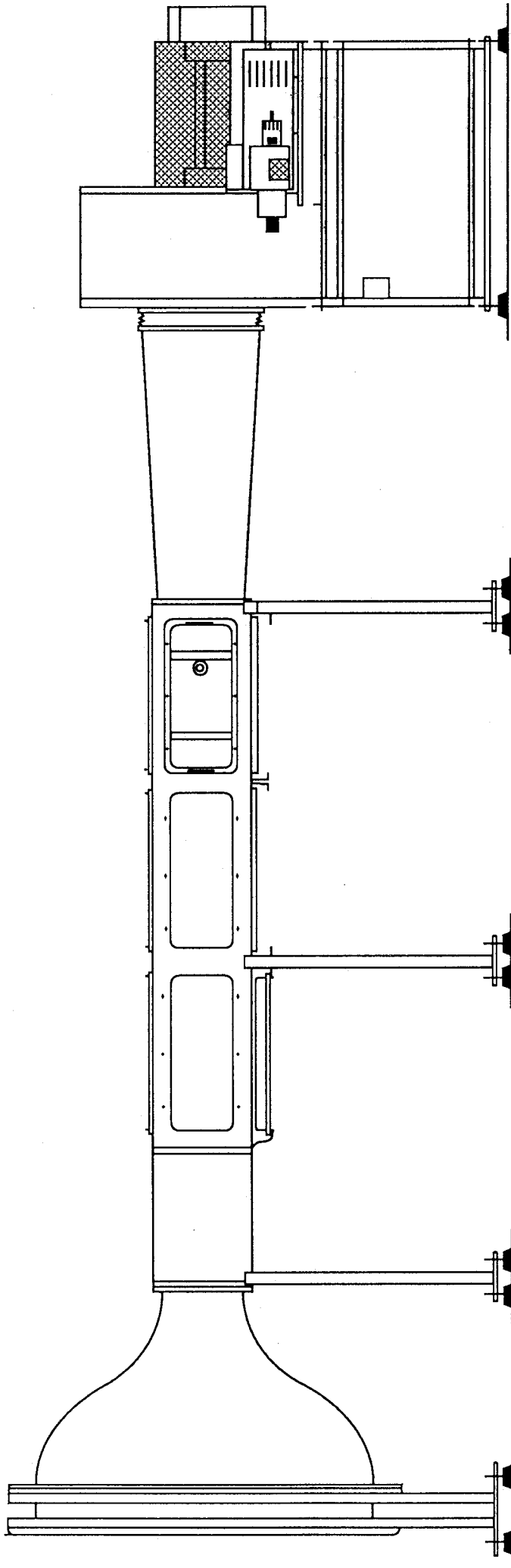


Figure 2-1 Soufflerie de couche limite

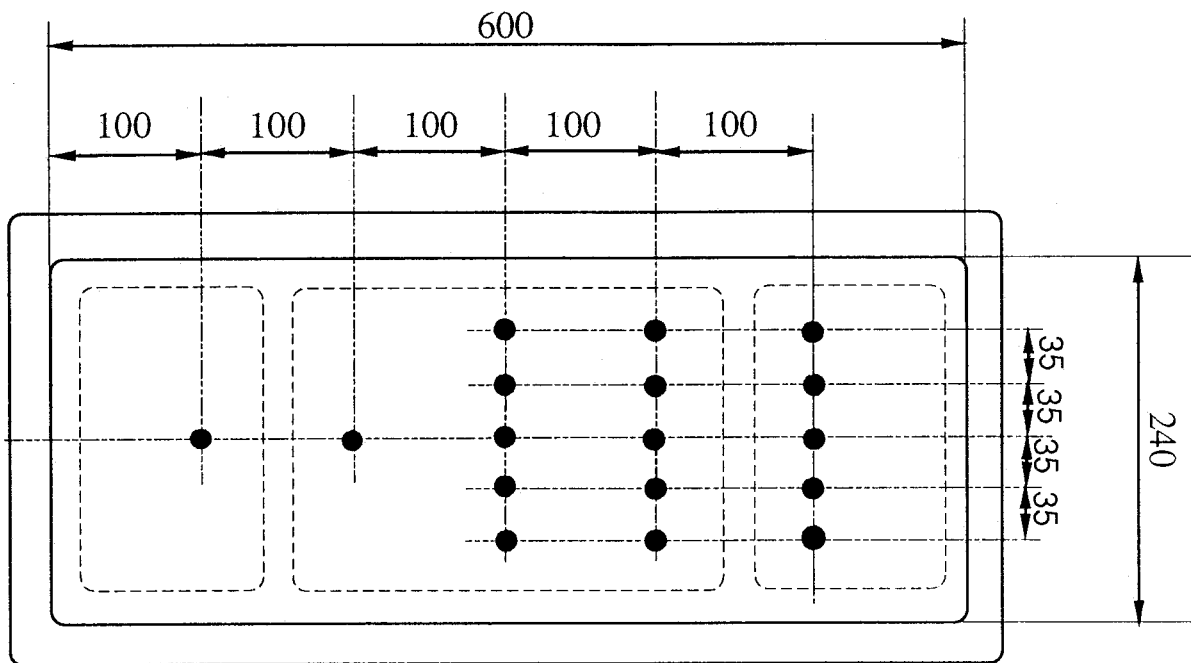


Figure 2-2 Schéma d'une plaque de paroi latérale équipée de prises de pression

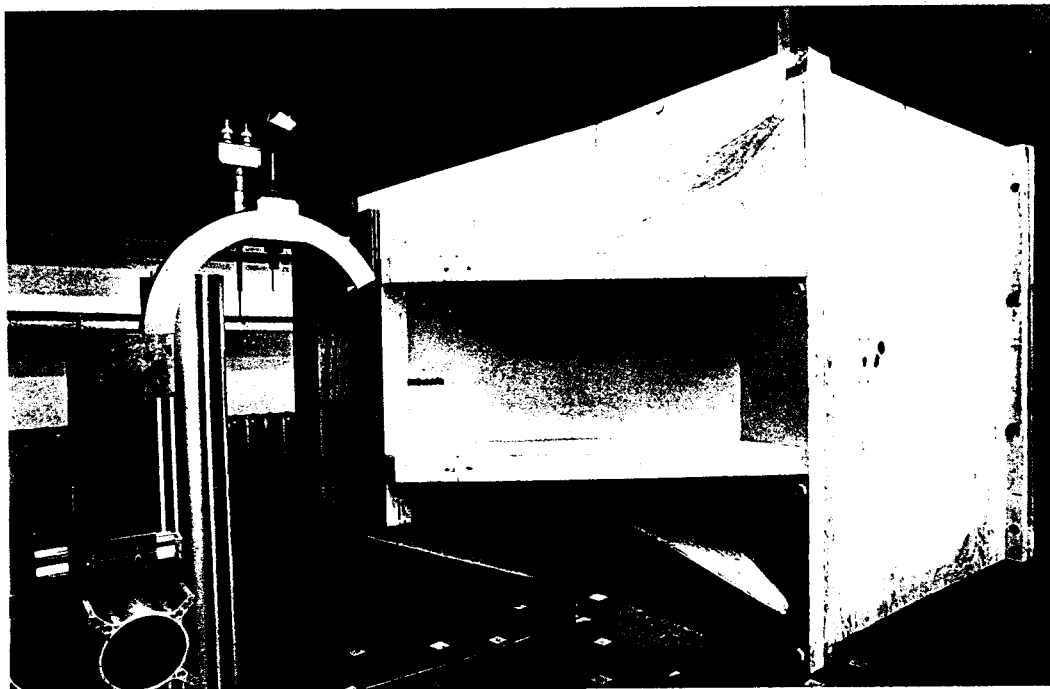


Figure 2-3 Soufflerie d'étalonnage

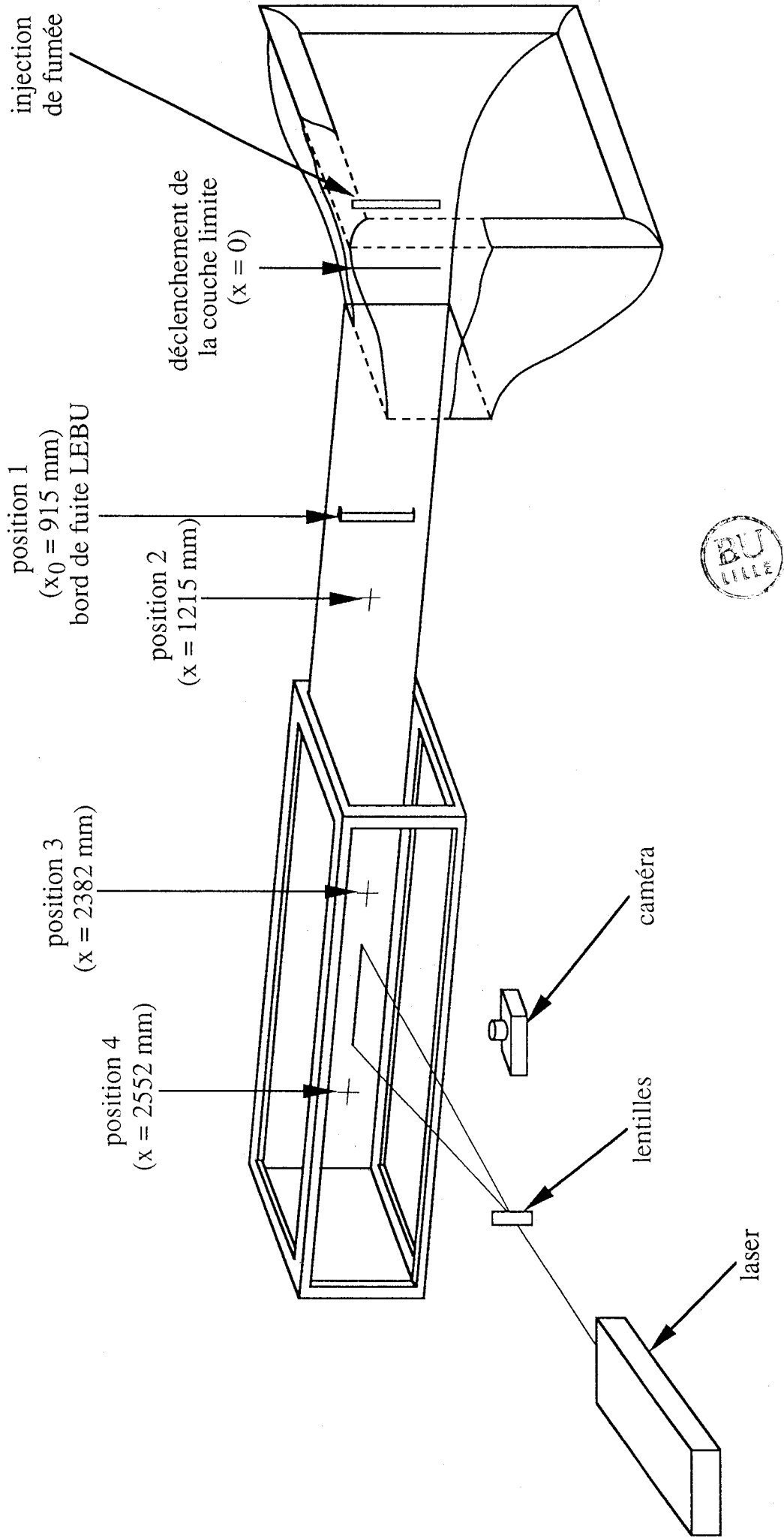


Figure 2-4 Schéma de la plaque dans la première configuration d'essais

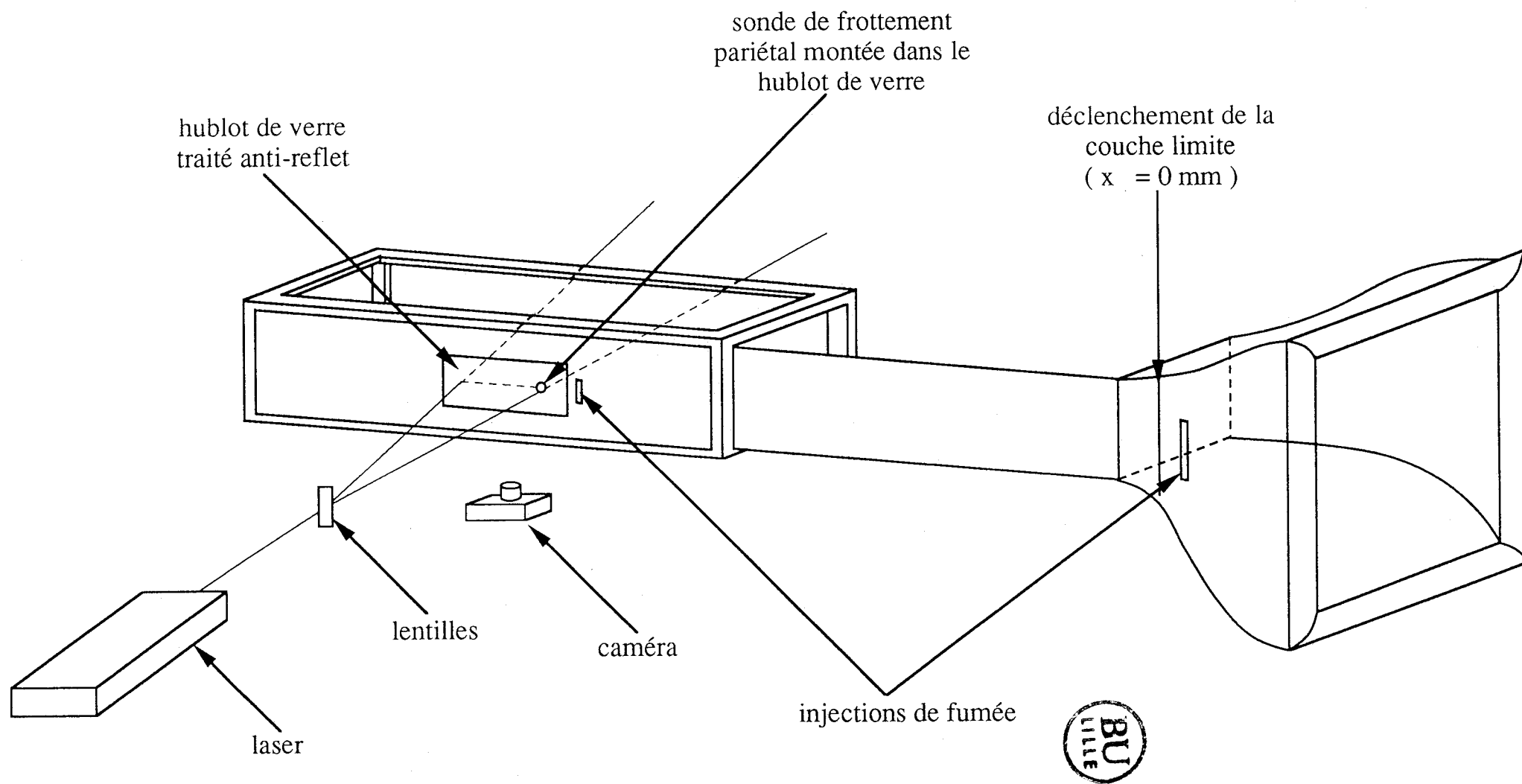
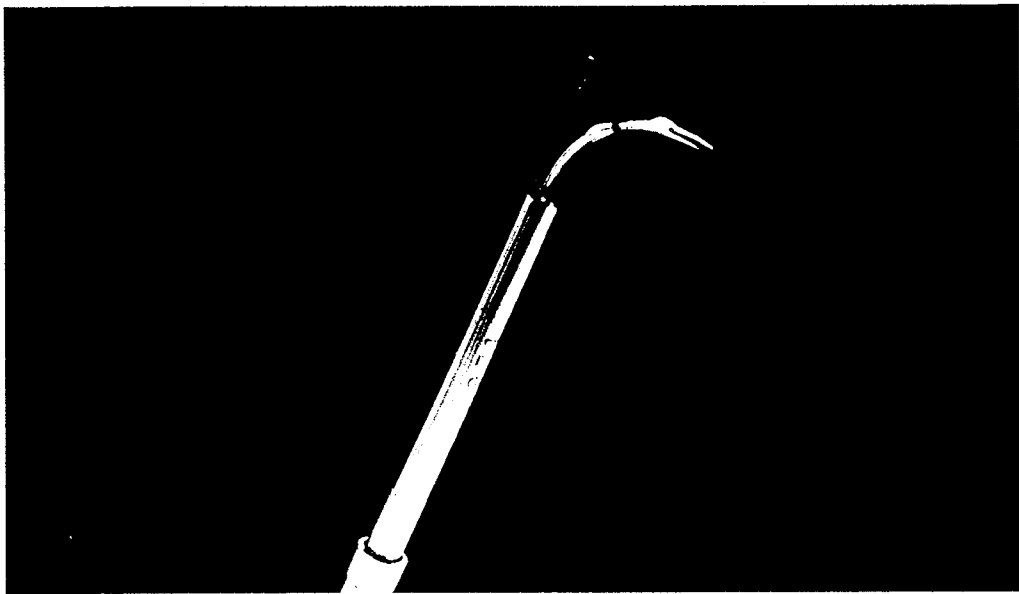


Figure 2-5 Schéma de la plaque dans la deuxième configuration d'essais



Sonde à fil simple



Sonde à fils croisés

Figure 2-6 Sondes à fils chauds utilisées

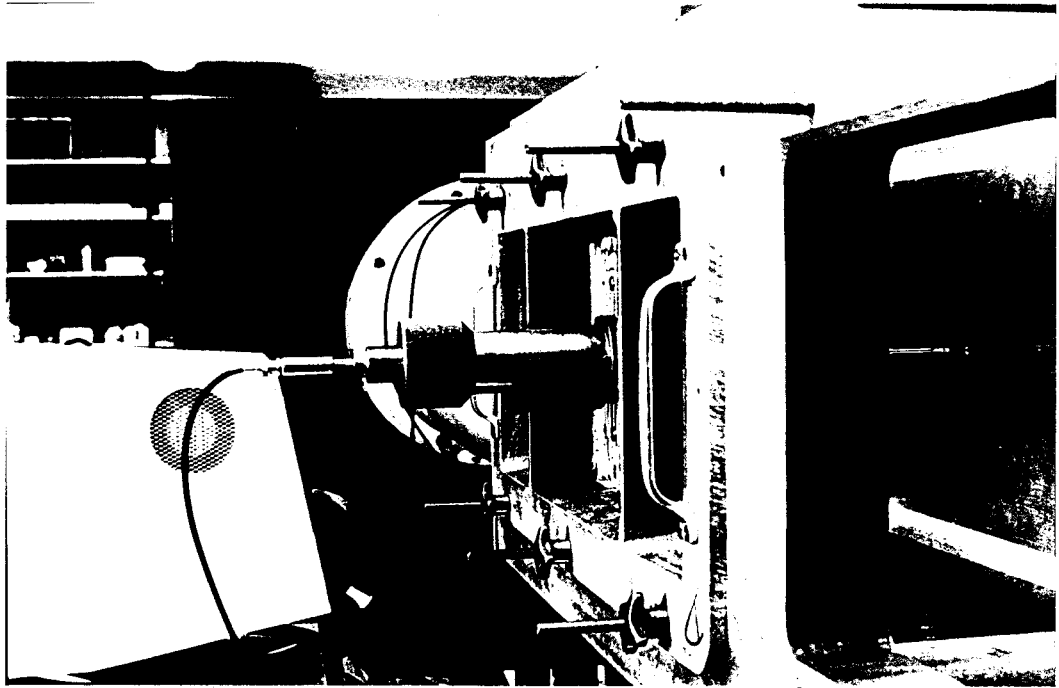


Figure 2-7 Dispositif de mesure au fil chaud

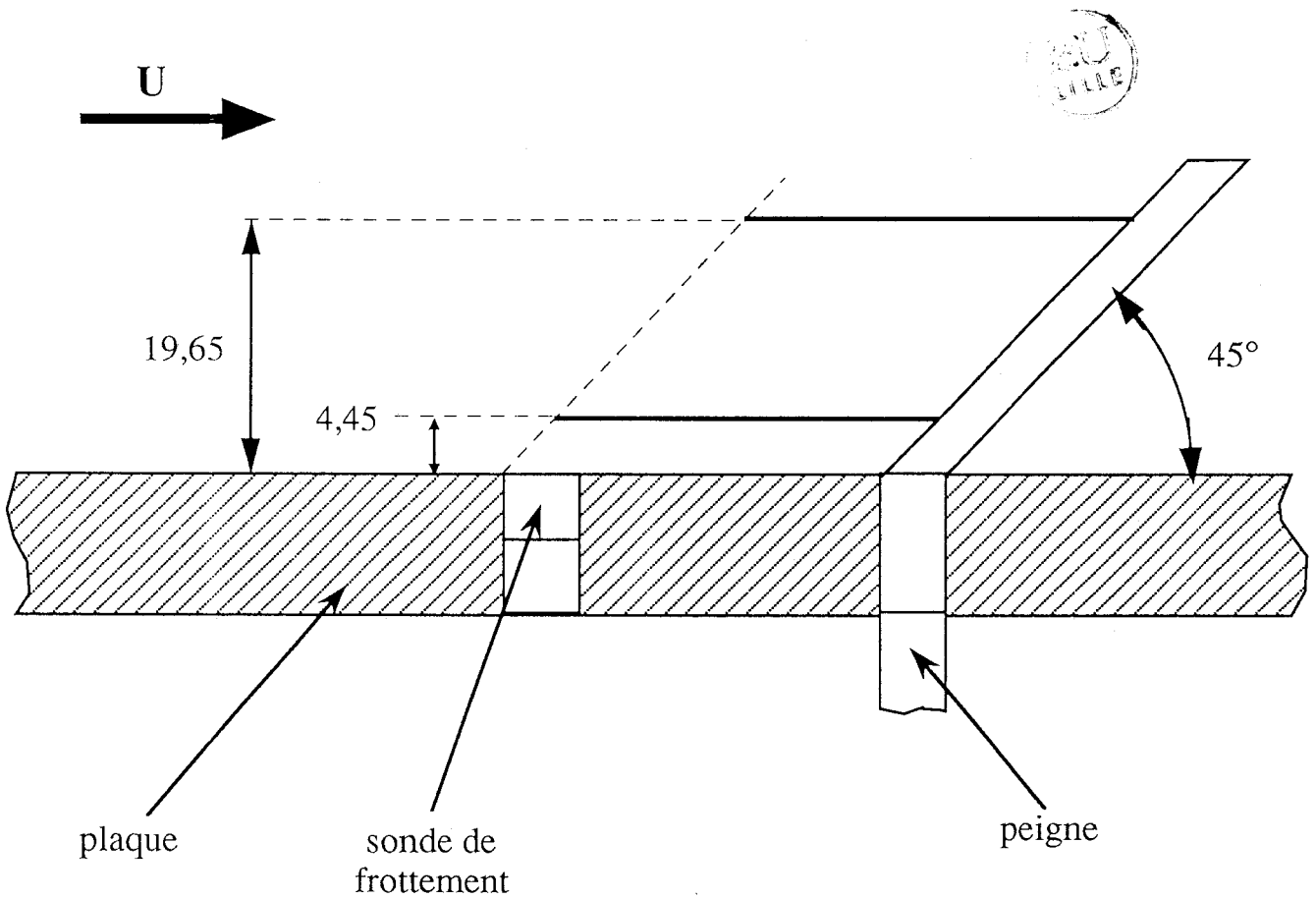


Figure 2-8 Position du peigne et de la sonde de frottement dans la couche limite lors de la première configuration d'essais

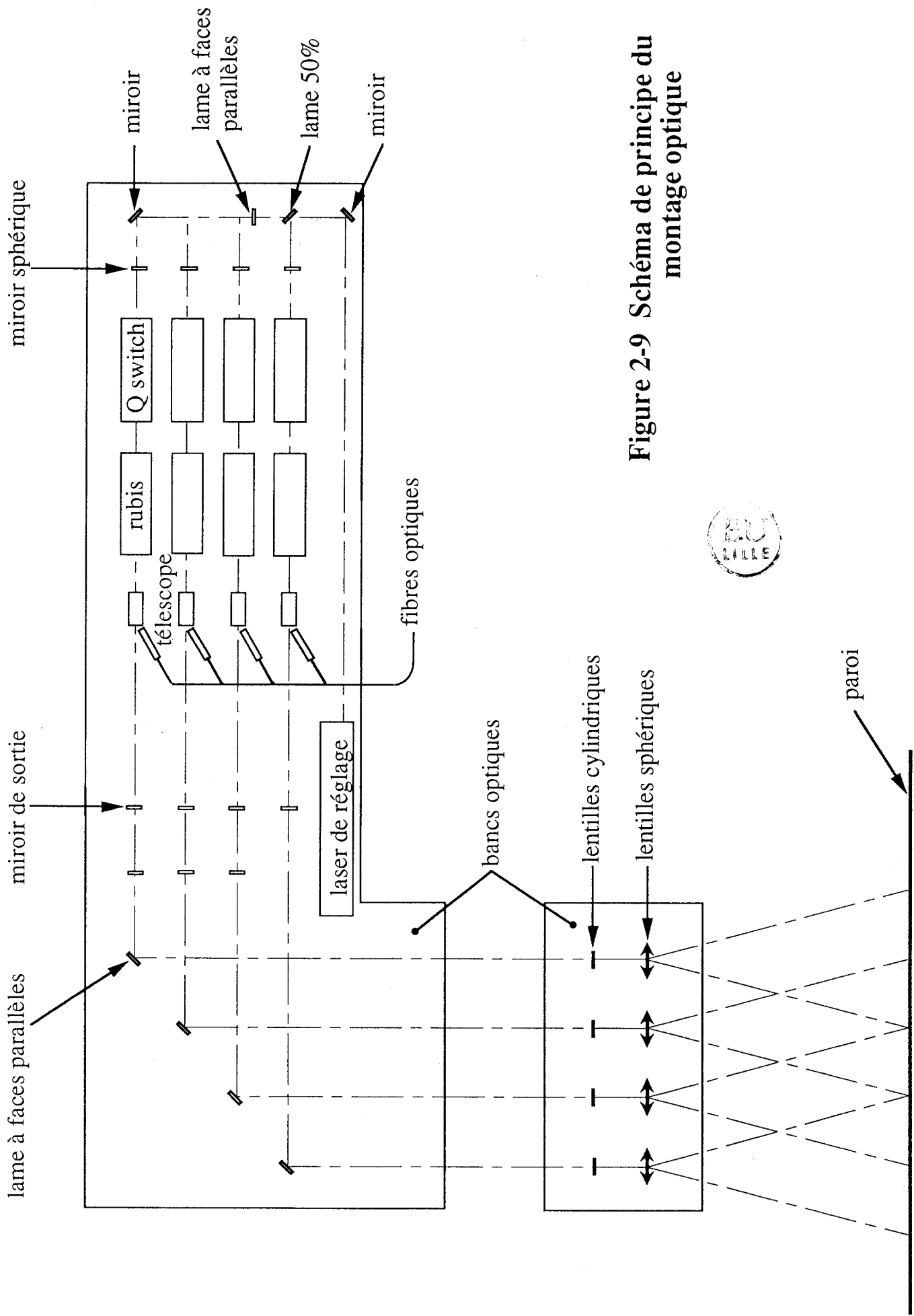


Figure 2-9 Schéma de principe du montage optique

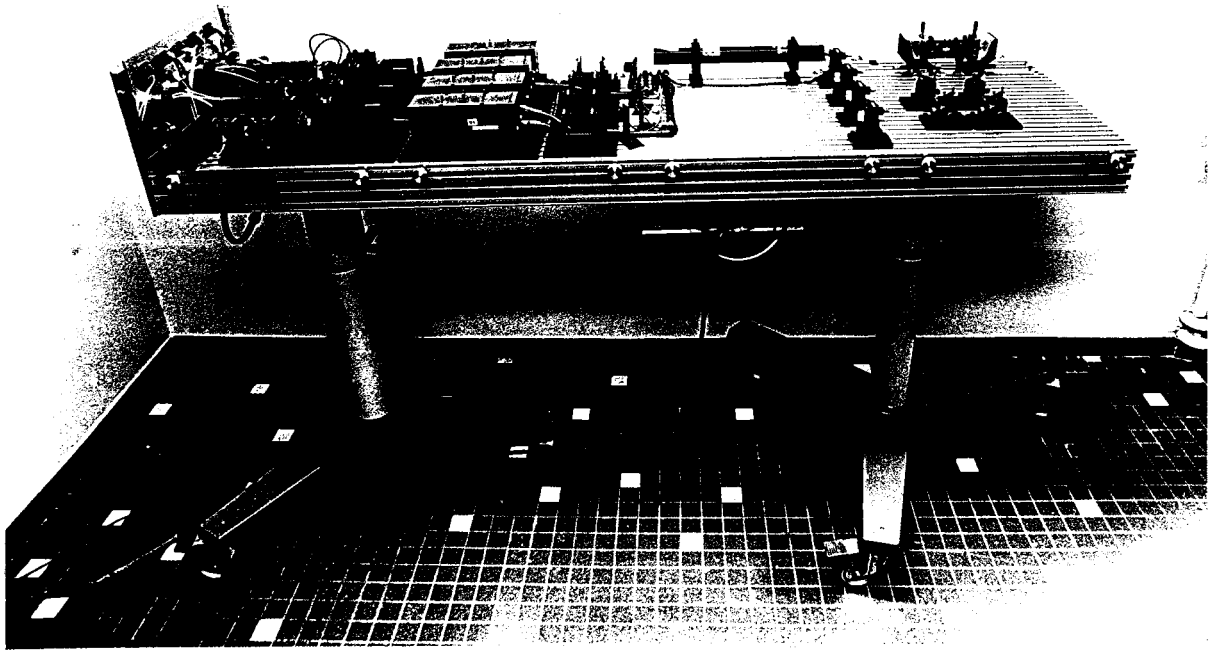


Figure 2-10 Les cavités laser à rubis

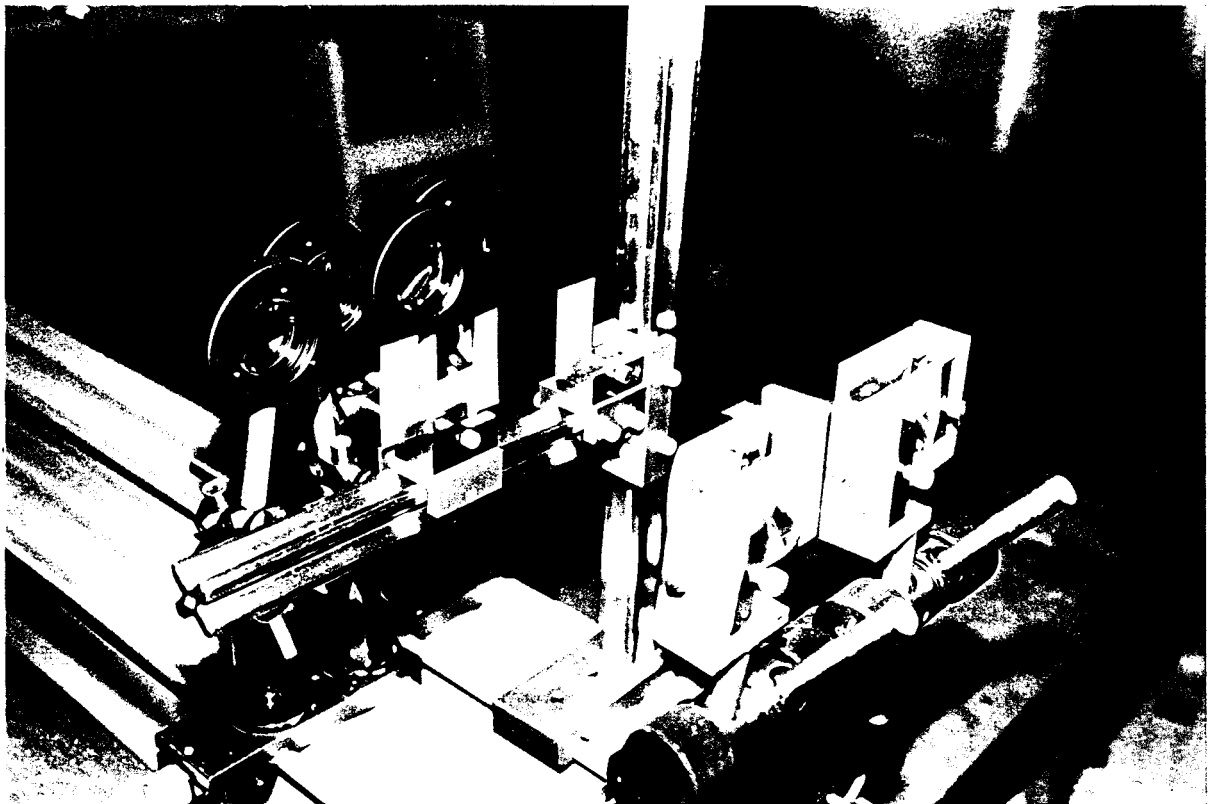


Figure 2-11 Système optique pour réaliser les plans lumineux

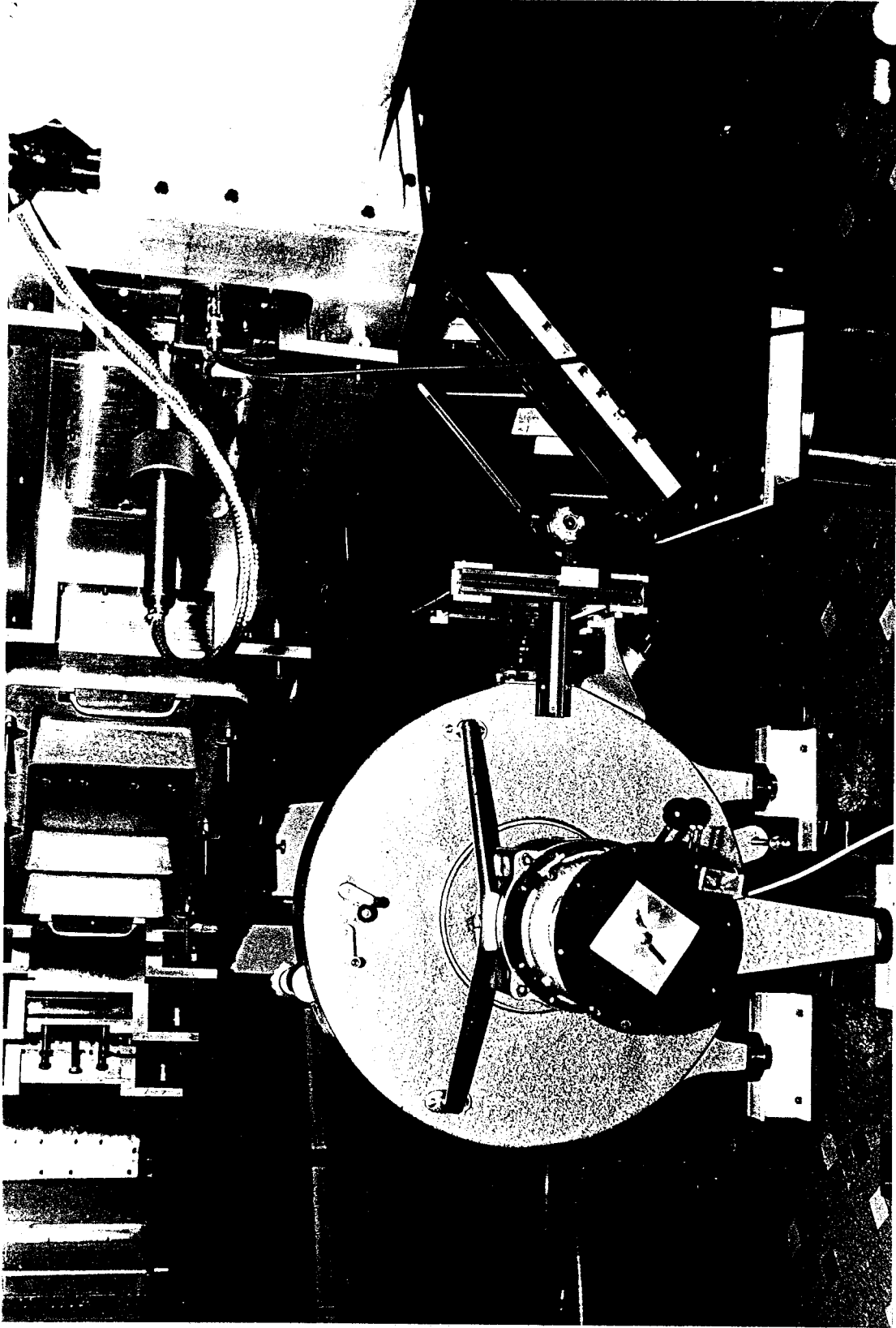
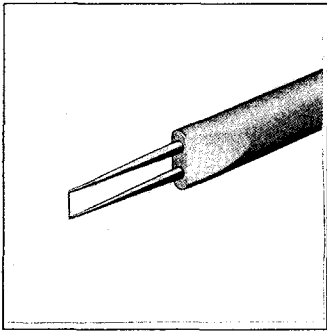
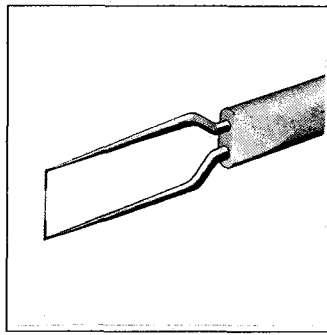


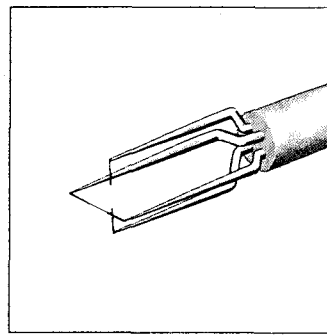
Figure 2-12 Système de prise de vues



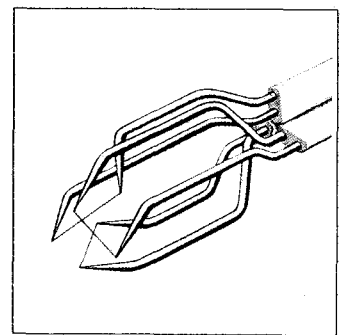
5 μm-dia. platinum-plated tungsten wire, welded to the prongs



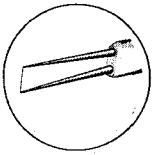
5 μm-dia. platinum-plated tungsten wire, golded-plated at the ends to provide active sensor length of 1.25 mm



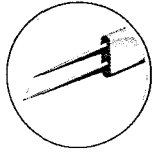
sensor arrangement of X-probe



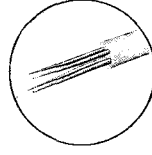
tip of triple-sensor probe



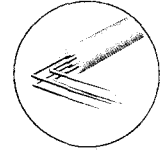
straight prongs, sensor perpendicular to probe axis



straight prongs of unequal length, sensor at angle of 45° to probe axis



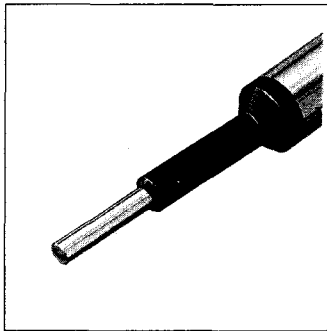
parallel-sensor probe straight prongs, parallel sensors



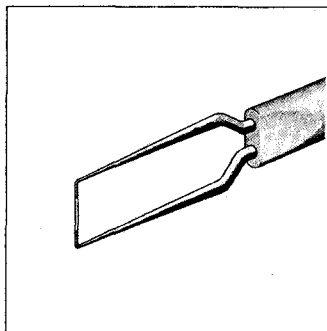
X-probe, right-angle prongs



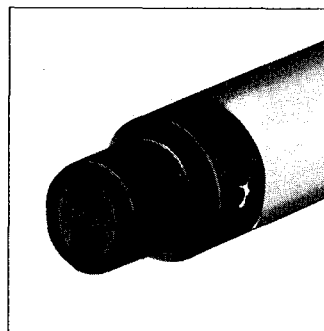
Exemples de sondes à fil(s) chaud(s)



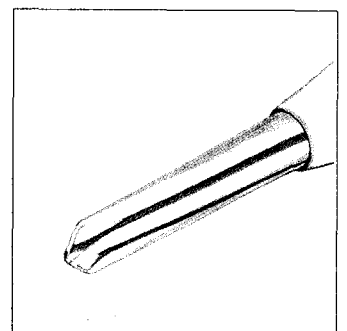
steel clad sensor



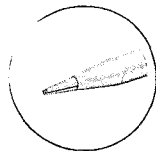
70 μm-dia. quartz fiber, with nickel film, golded-plated at the ends to provide active sensor length of 1.25 mm



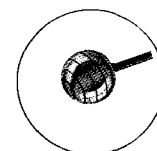
tip of flush-mounted probe



tip of V-film probe



conical probe



tip of omnidirectional probe

Exemples de sondes à film chaud

Figure 3-1 Différentes sondes à fil et film chaud (DISA)

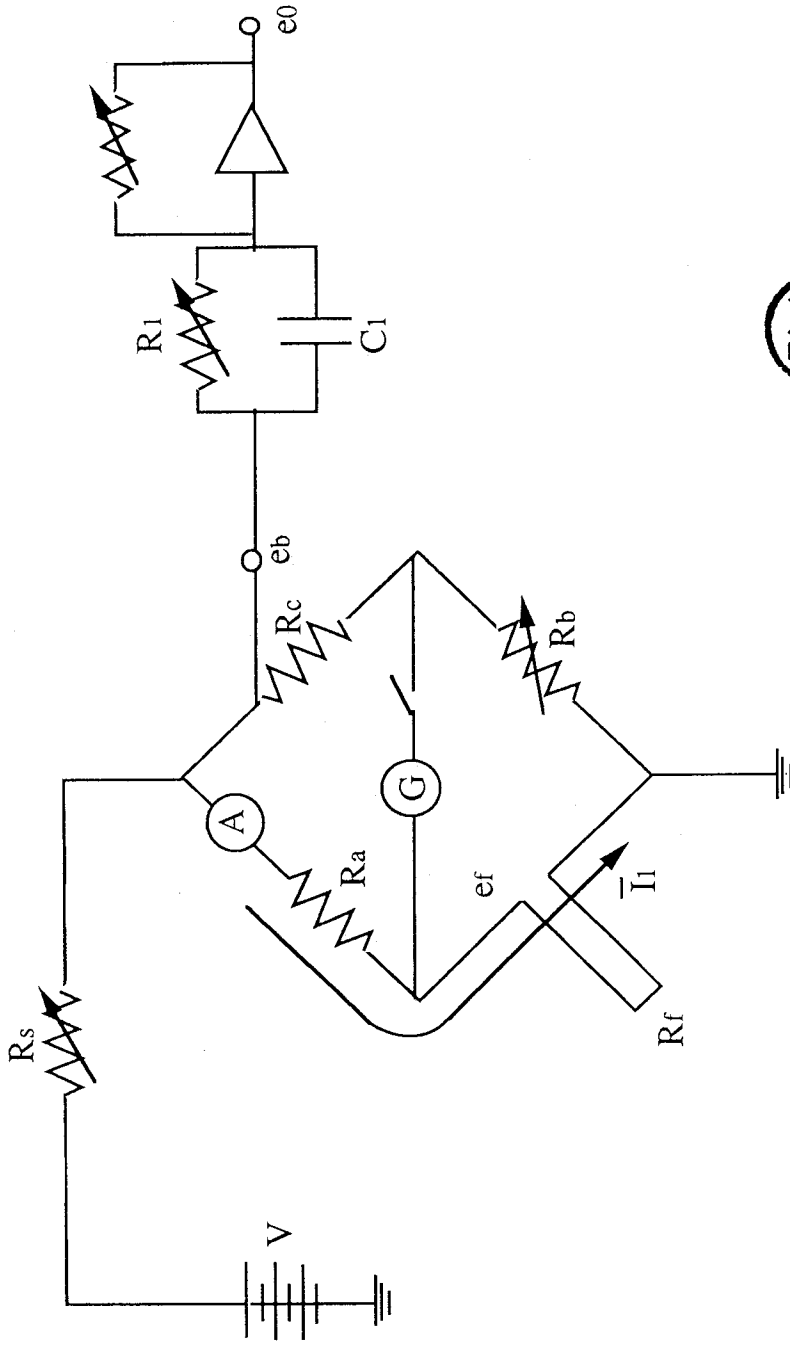


Figure 3-2 Circuit de l'anémomètre à courant constant

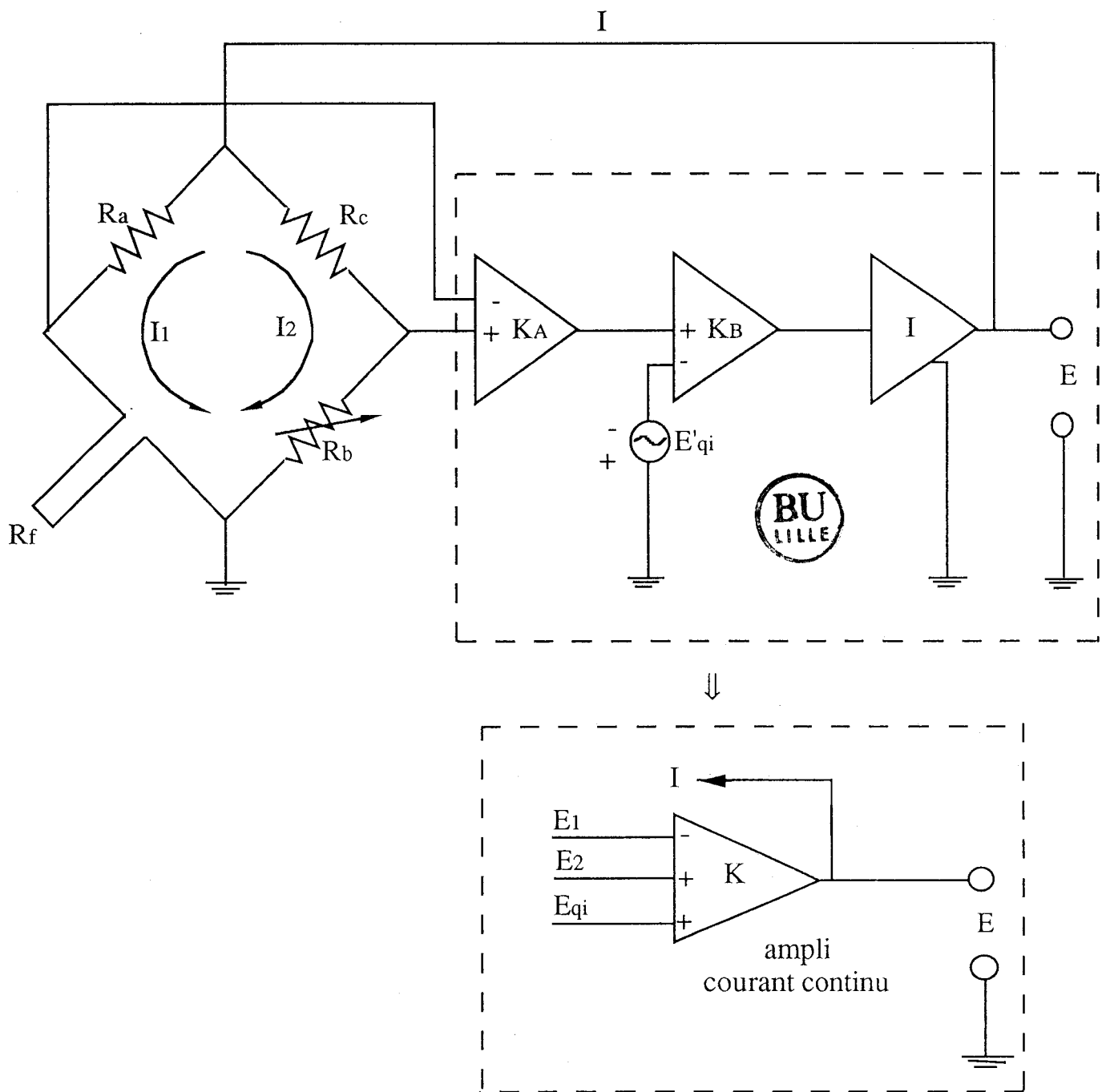
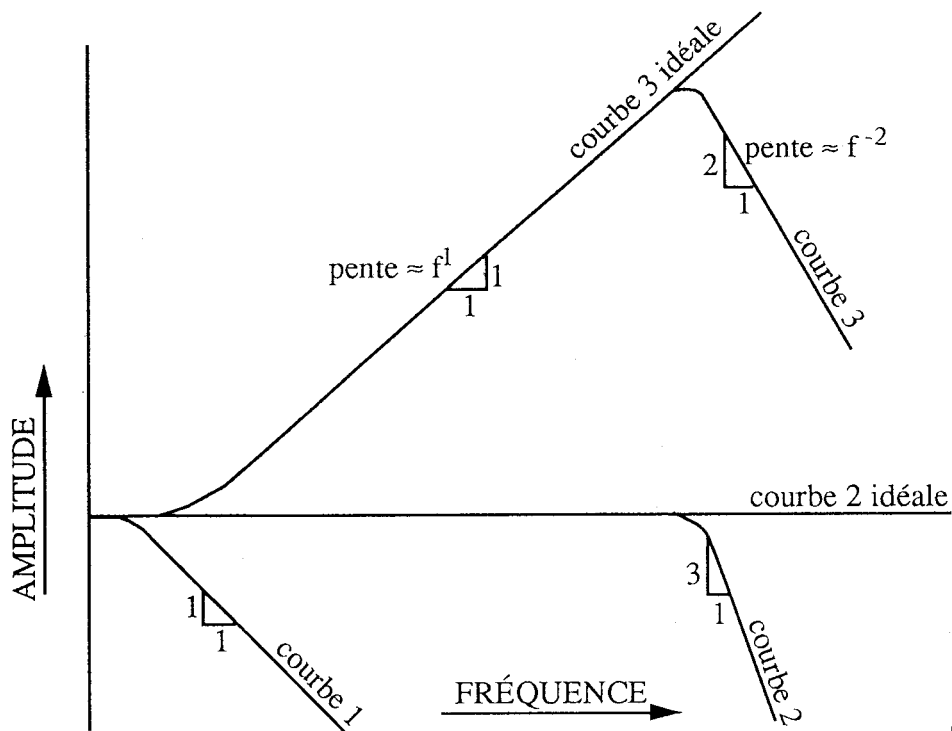


Figure 3-3 Circuit de l'anémomètre à température constante



réponse aux fluctuations de vitesse:

- courbe 1 : réponse du fil chaud sans circuit de compensation
- courbe 2 idéale : réponse idéale du fil chaud avec contrôle à température constante
- courbe 2 : réponse réelle du fil chaud avec contrôle à température constante

réponse au test sinusoïdal

- courbe 3 idéale : réponse idéale du fil chaud avec contrôle à température constante
- courbe 3 : réponse réelle du fil chaud avec contrôle à température constante

Figure 3-4 Réponses en fréquence de l'anémomètre à température constante

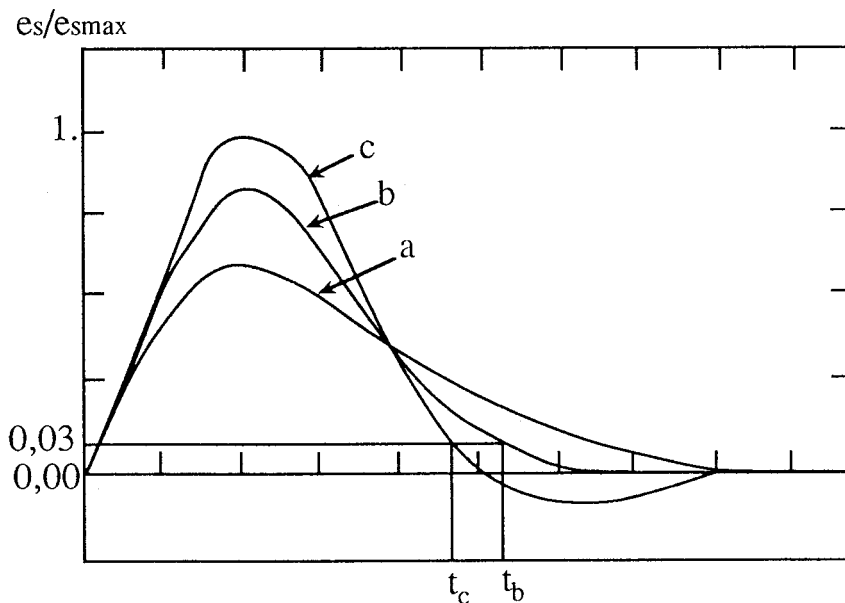


Figure 3-5 Signal de sortie de l'anémomètre à température constante en réponse au signal carré

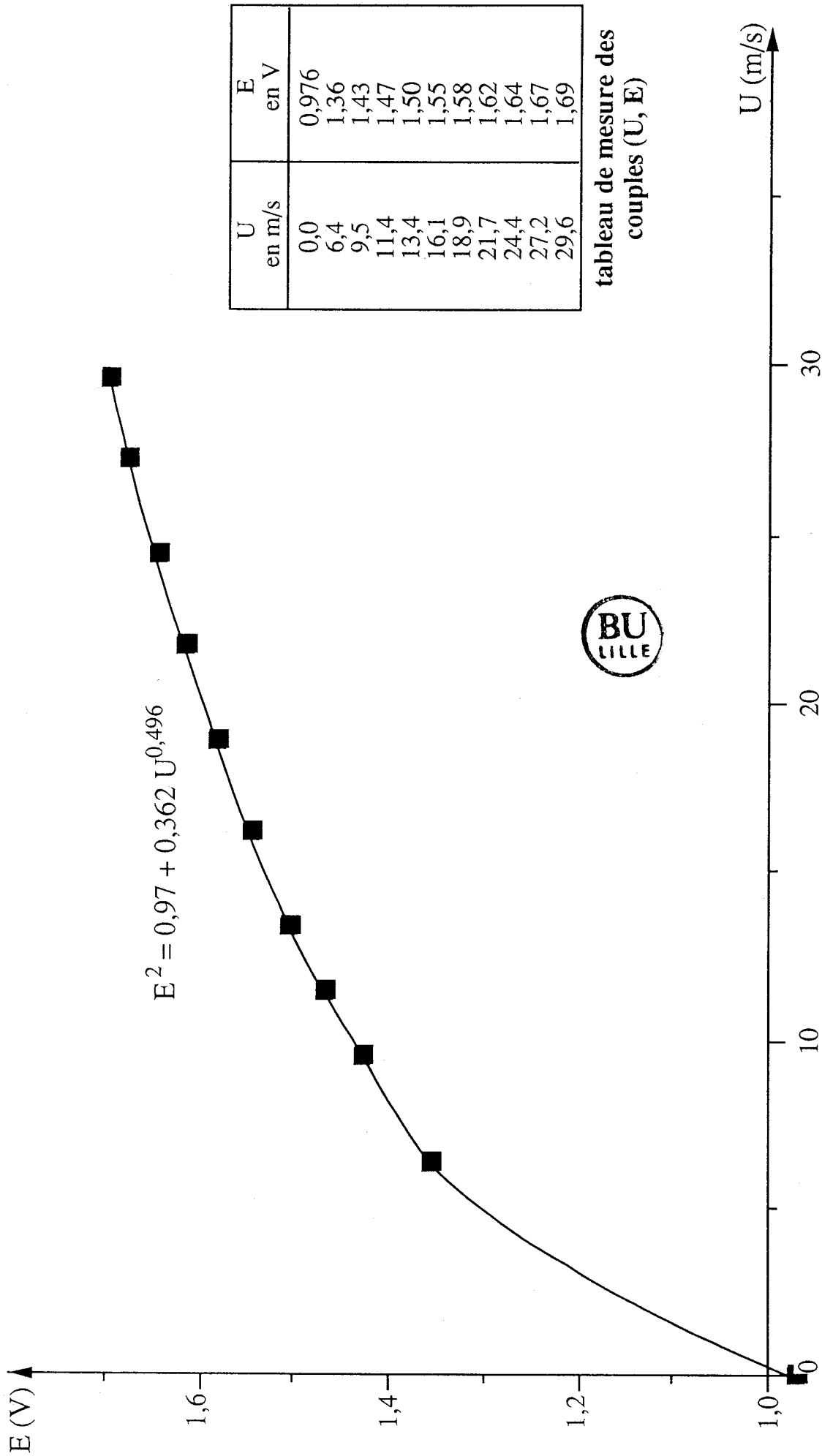


Figure 3-6 Exemple de courbe d'étalonnage du fil chaud simple

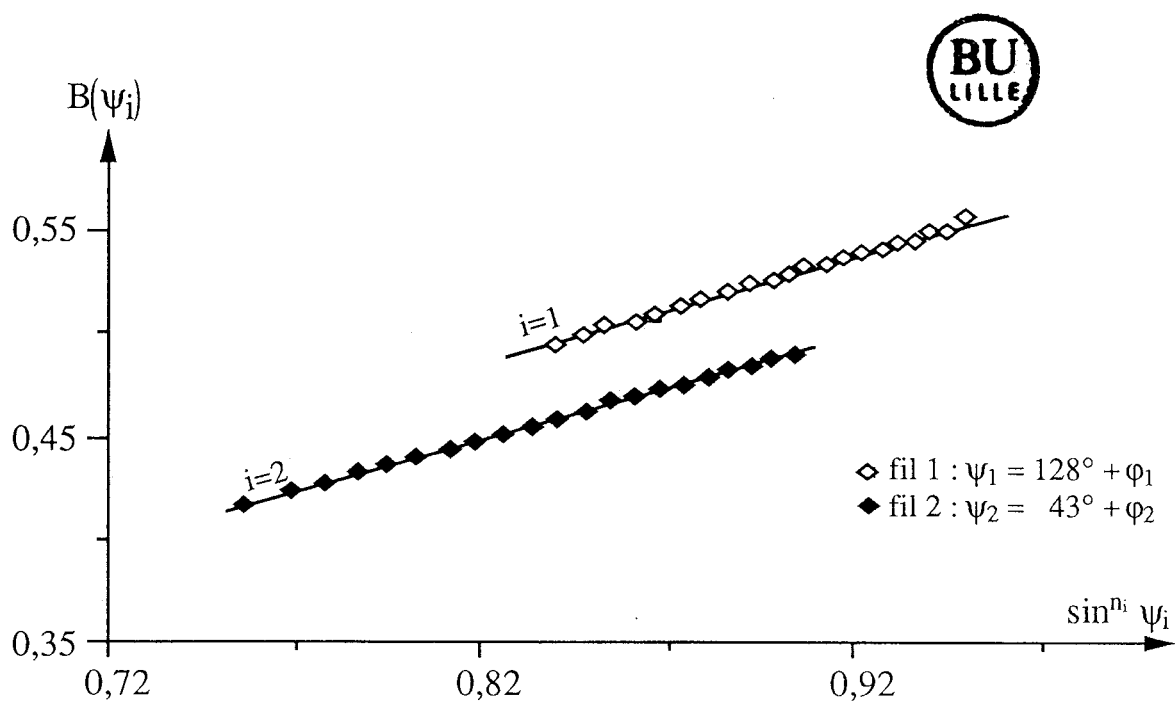
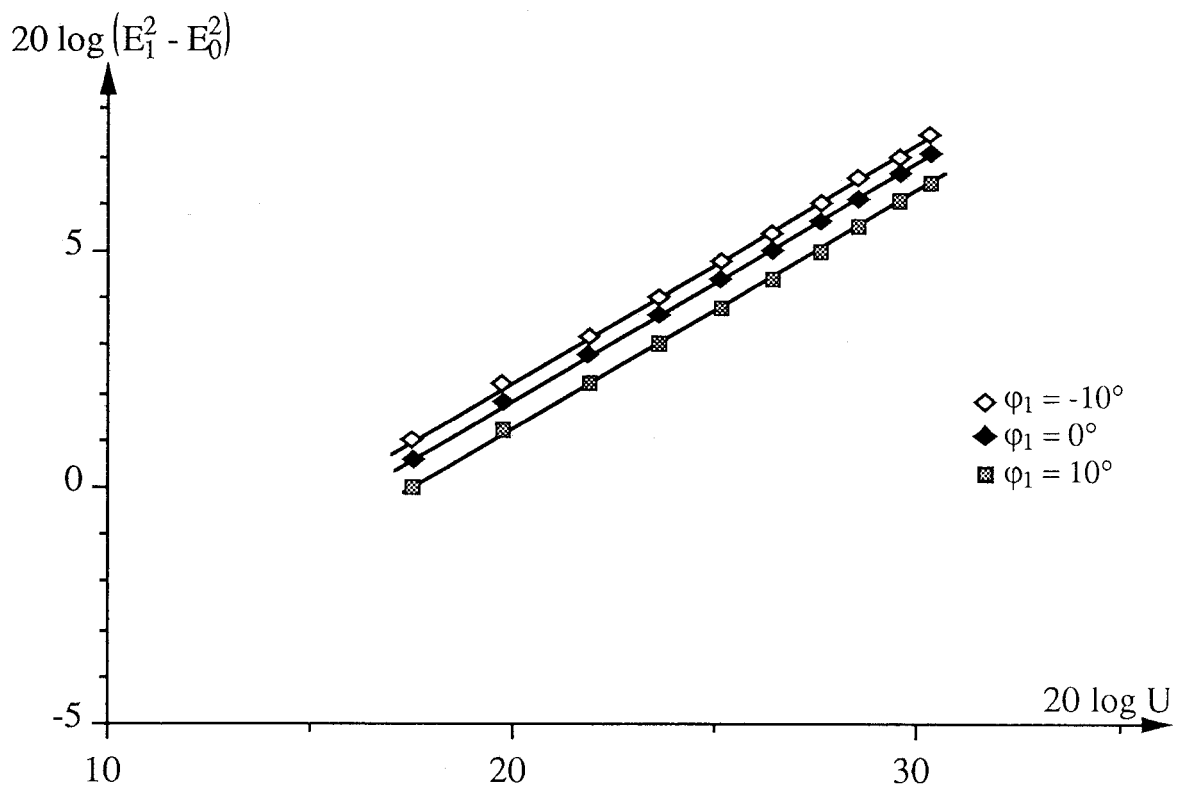


Figure 3-7 Courbes de calibration des fils croisés

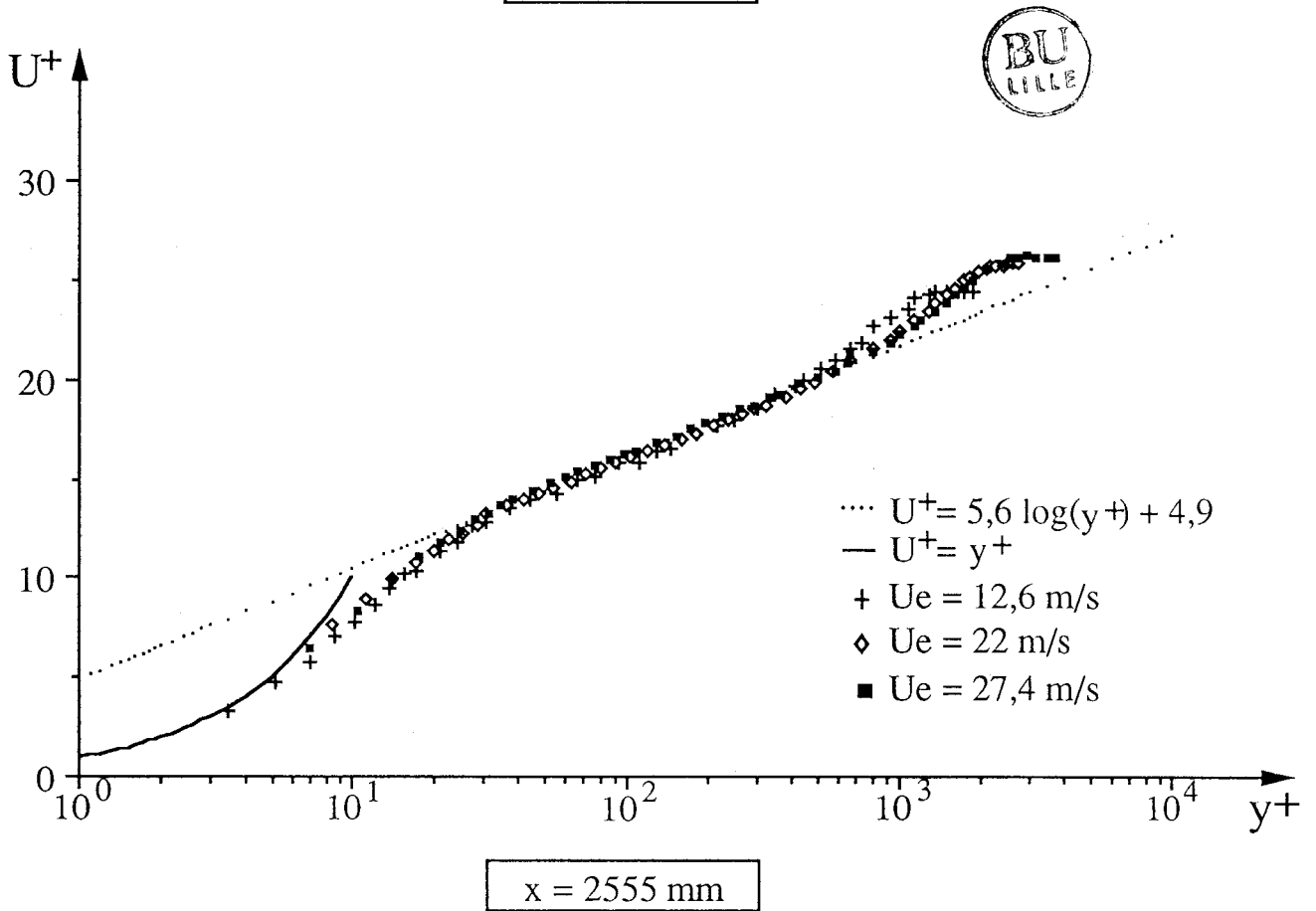
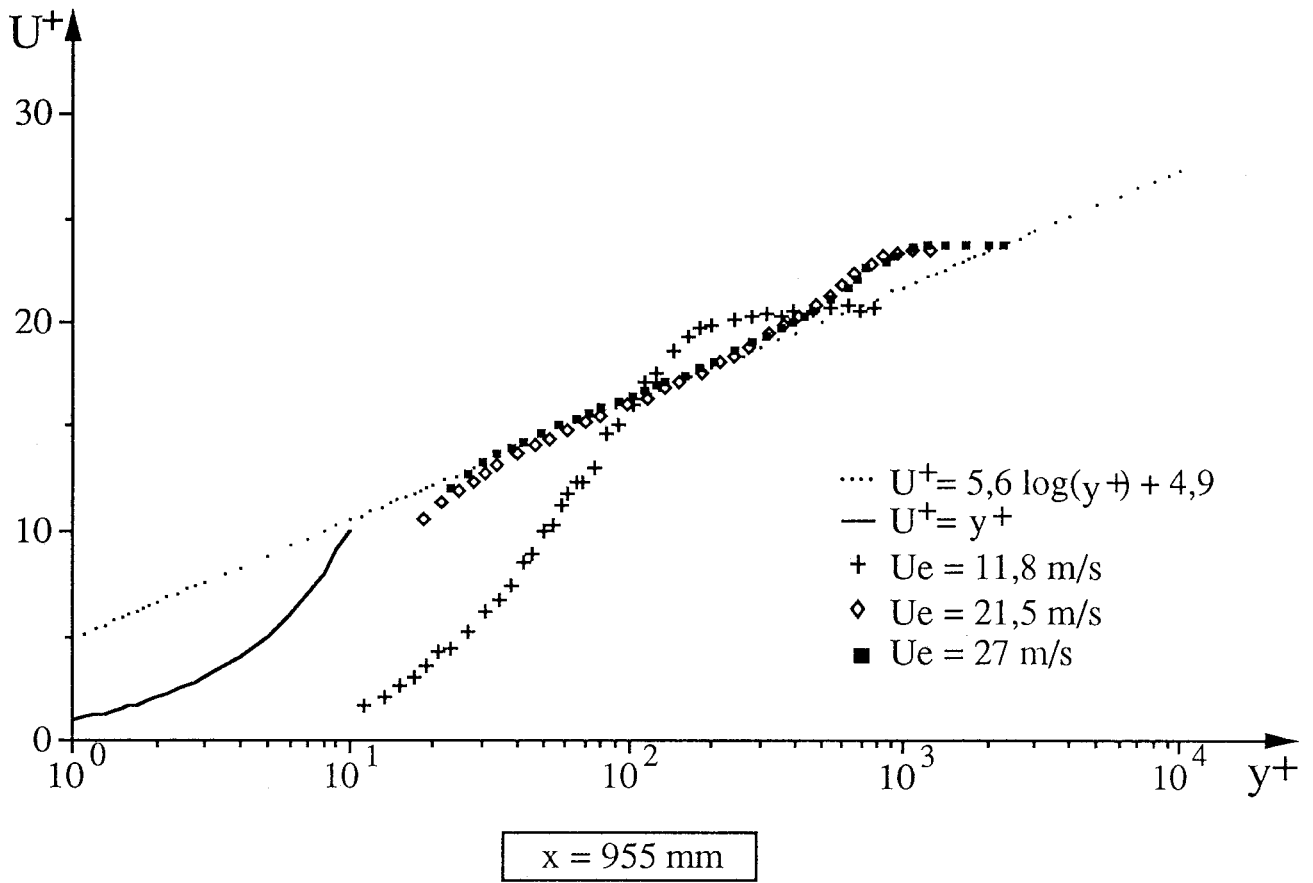


Figure 3-8 Vitesse moyenne en représentation logarithmique

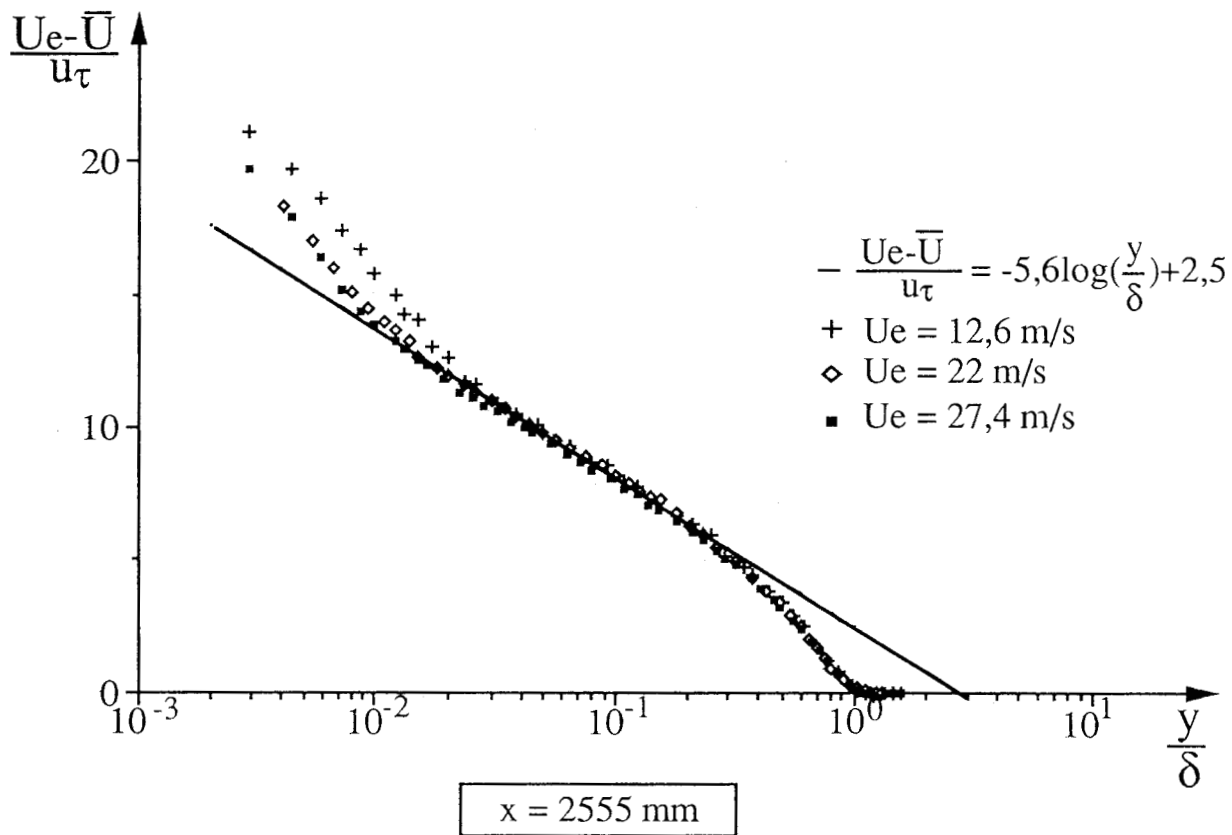
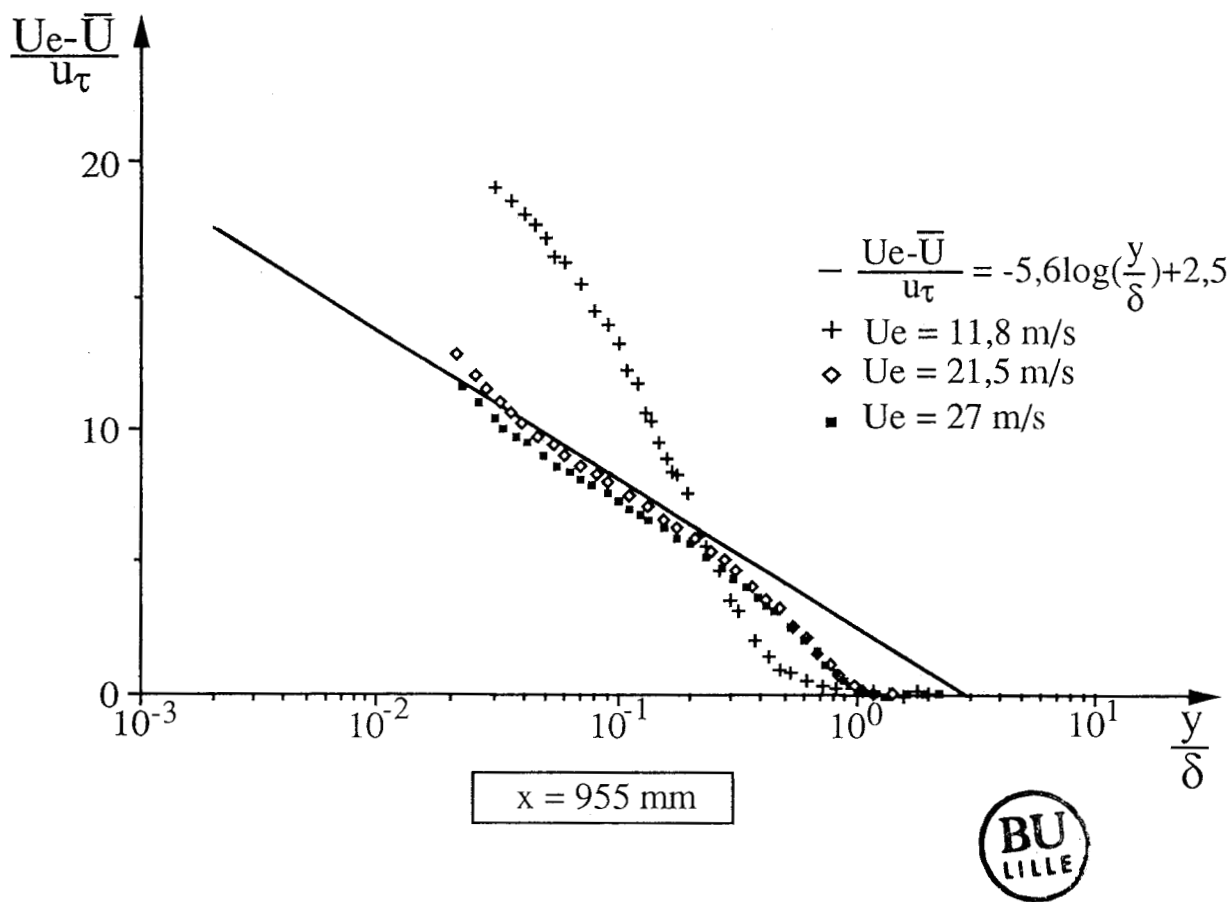


Figure 3-9 Vitesse moyenne déficitaire

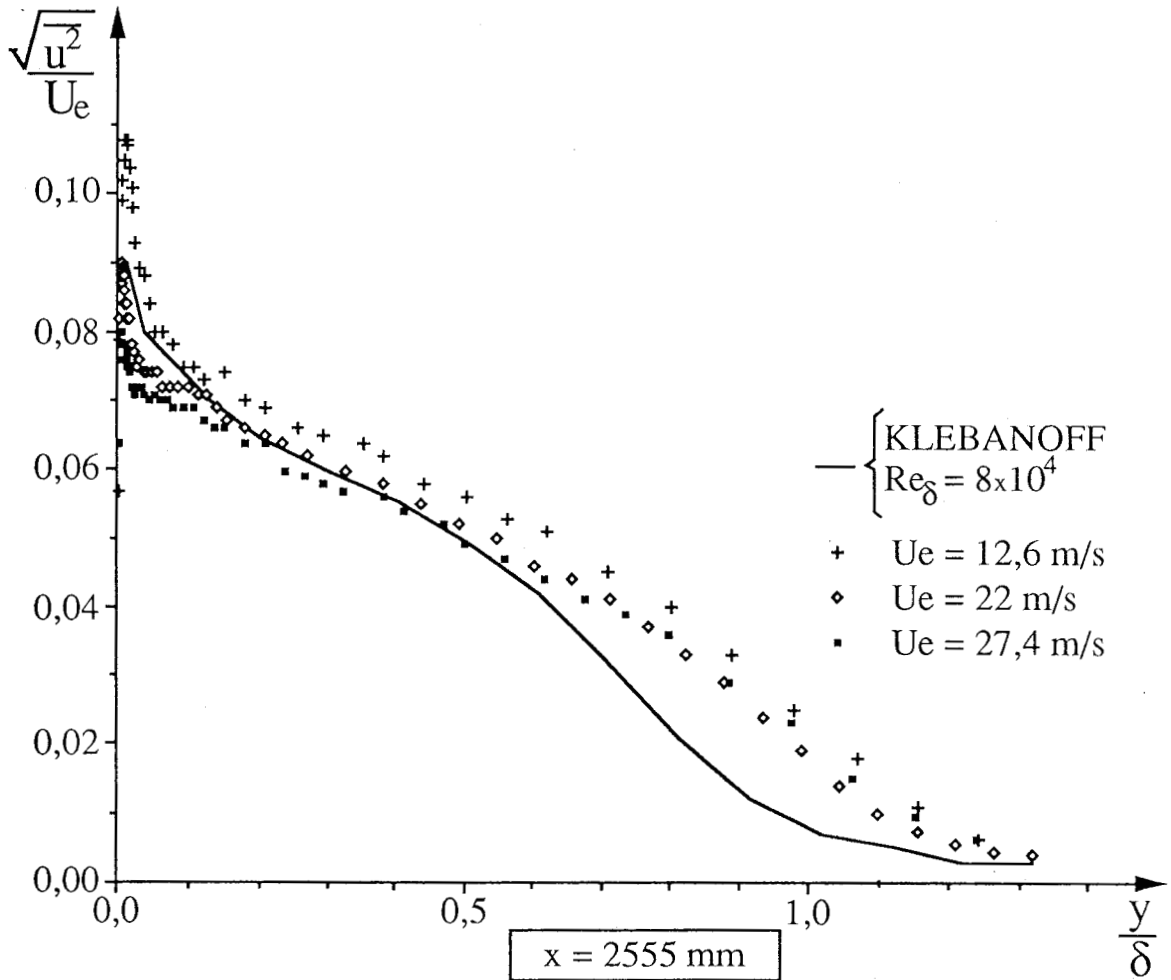
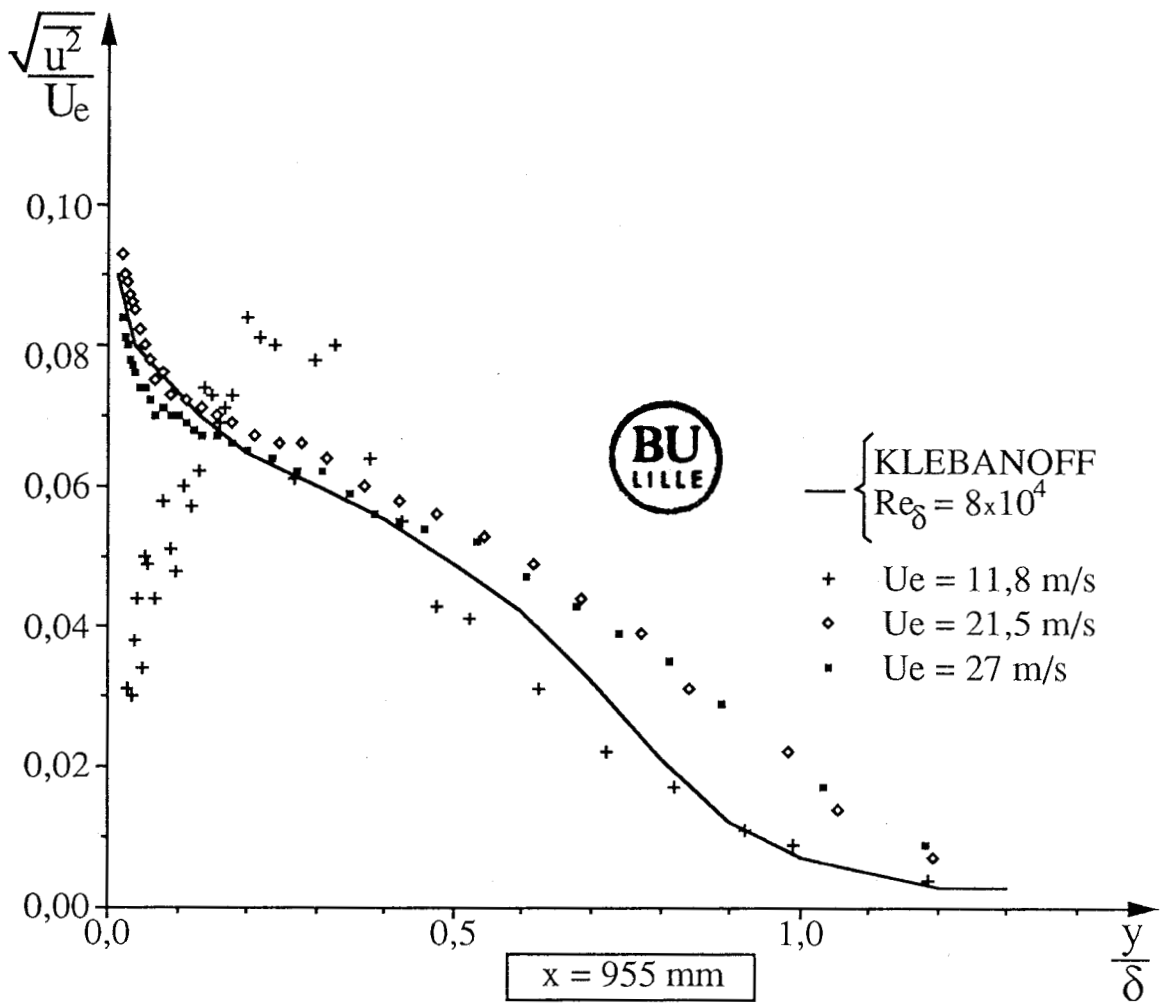


Figure 3-10 Intensité de turbulence

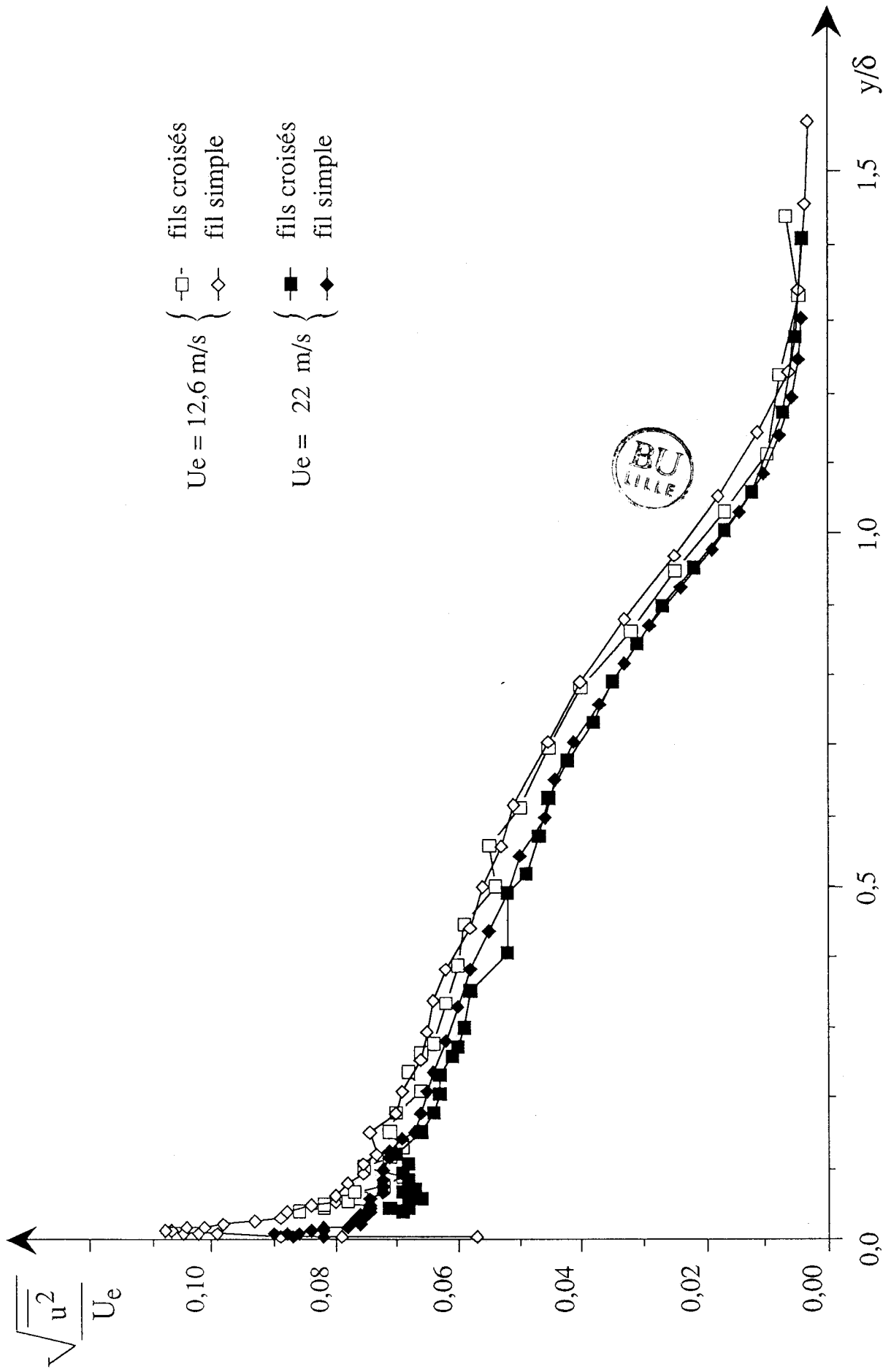


Figure 3-11 Comparaison des profils de la fluctuation longitudinale obtenus au fil simple et aux fils croisés
 $x = 2555 \text{ mm}$

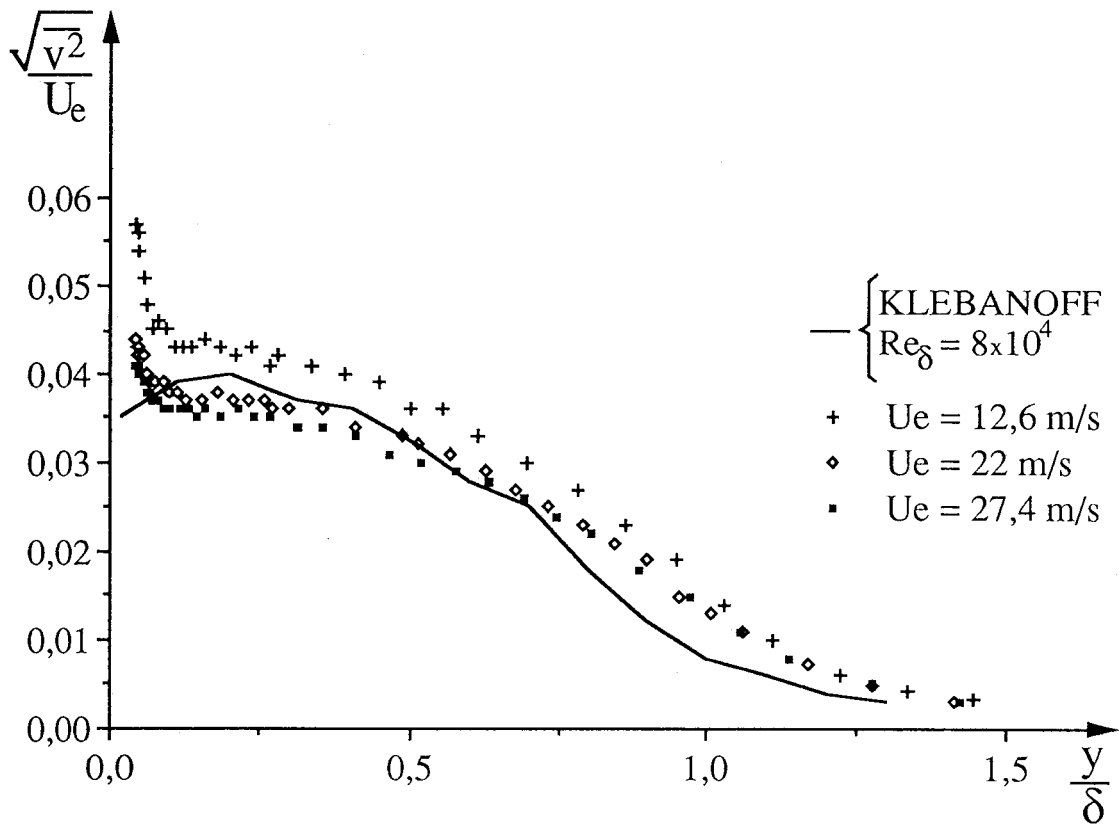


Figure 3-12 Fluctuation normale ($x = 2555 \text{ mm}$)

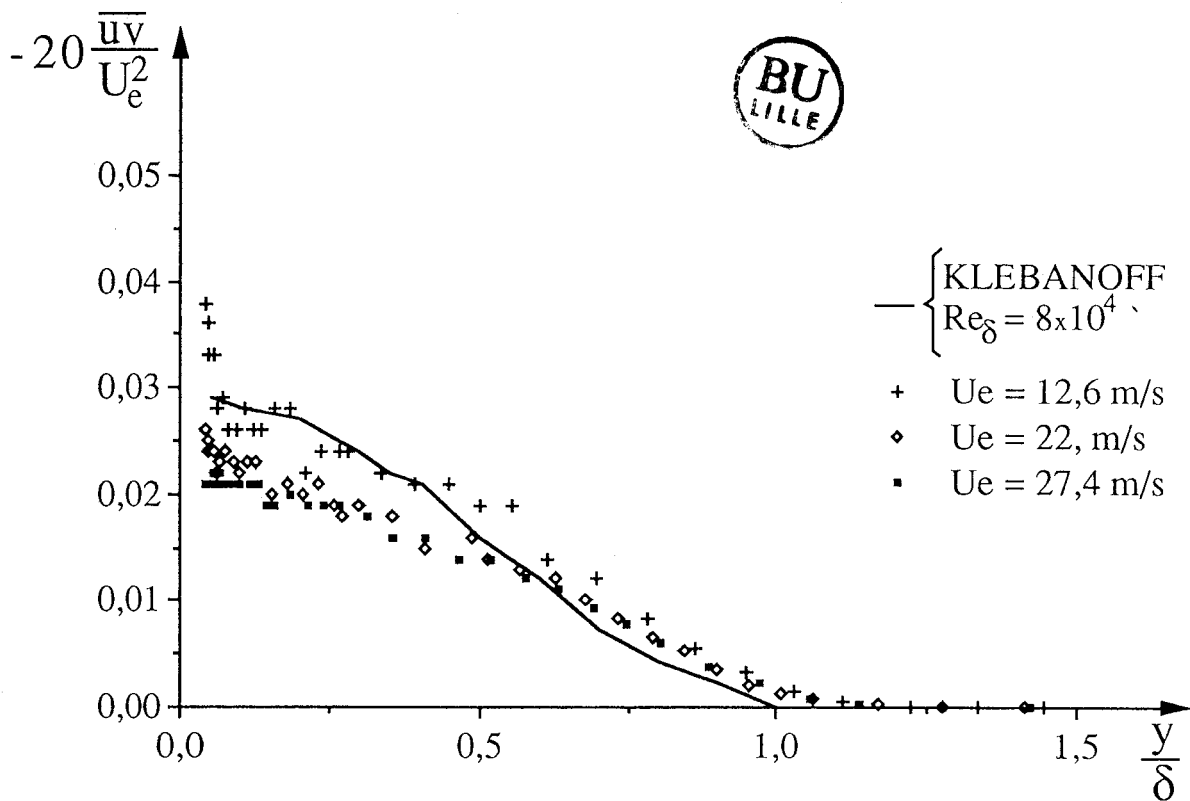
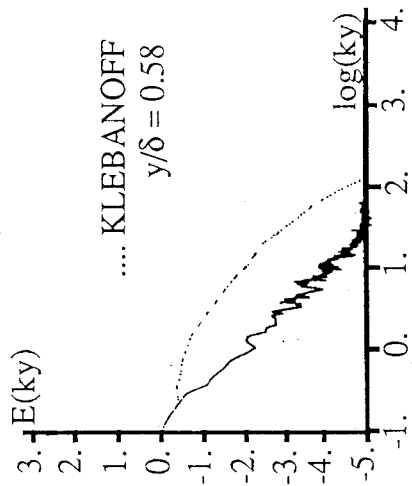
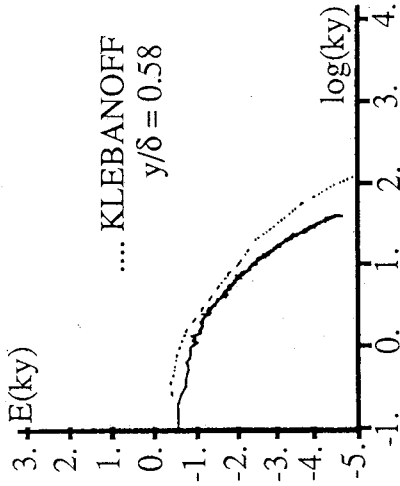


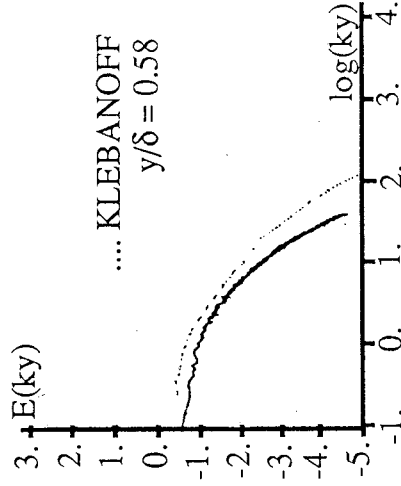
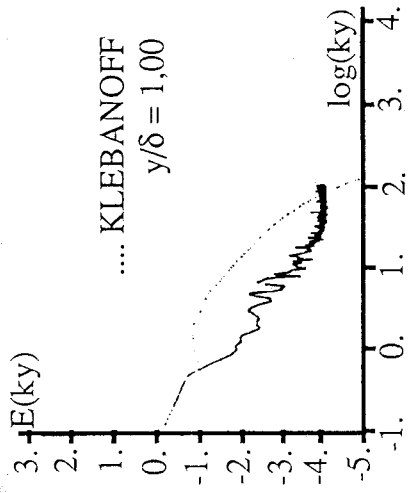
Figure 3-13 Contrainte de reynolds $-\overline{uv}$ ($x = 2555 \text{ mm}$)



$U_e = 11,8 \text{ m/s}$



$U_e = 21,5 \text{ m/s}$



$U_e = 27 \text{ m/s}$

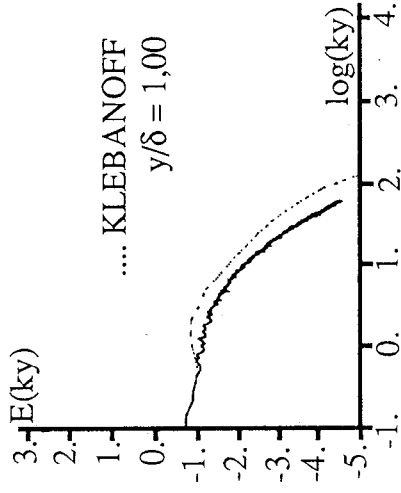
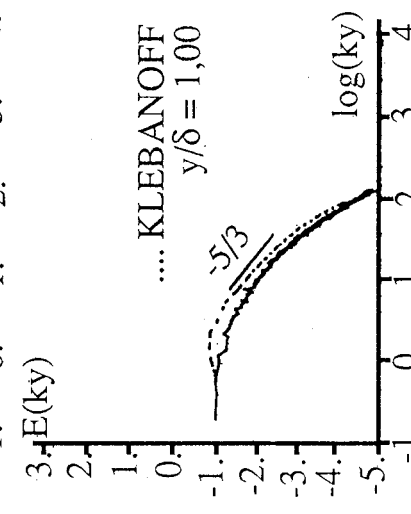
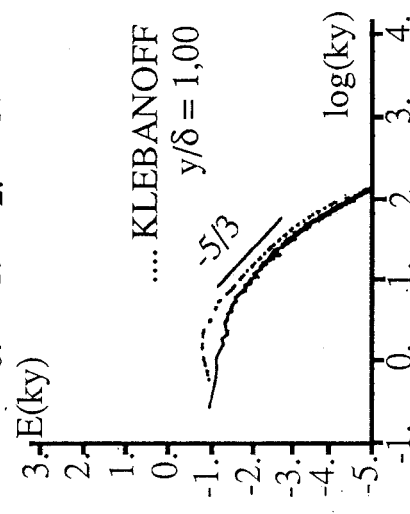
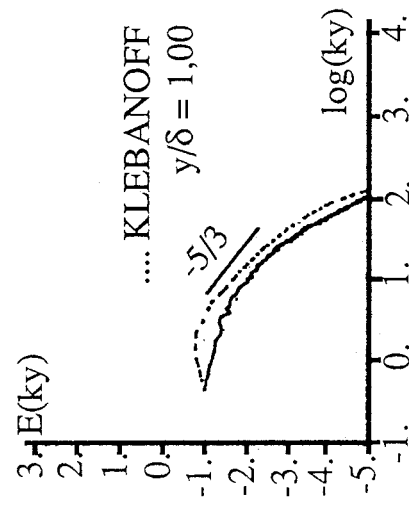
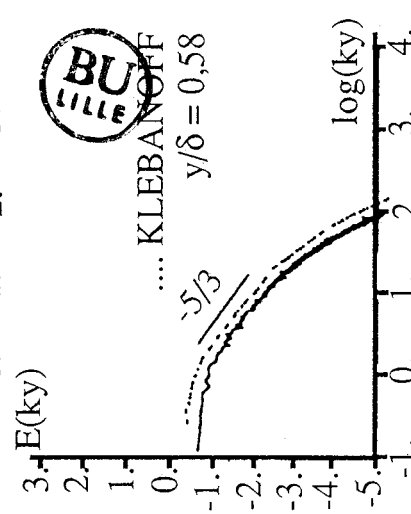
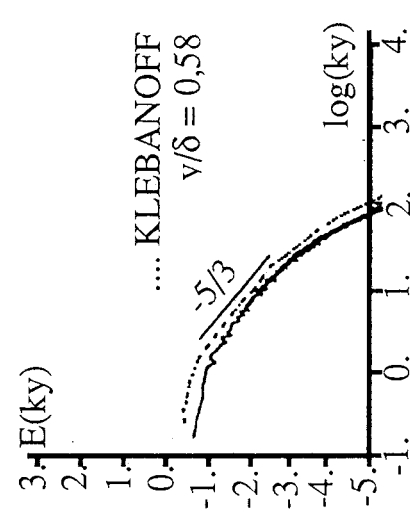
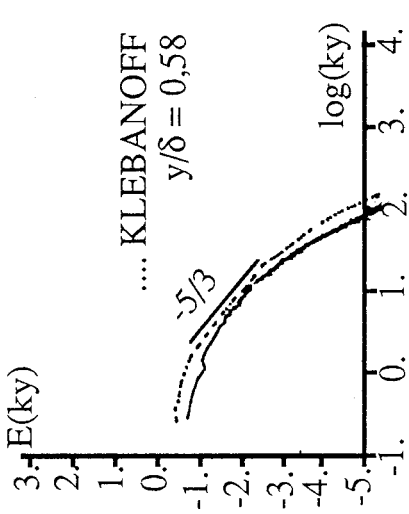
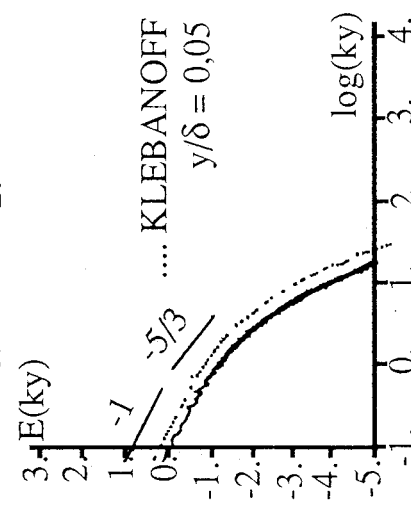
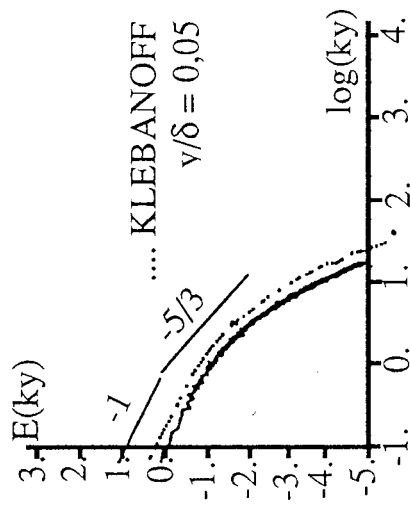
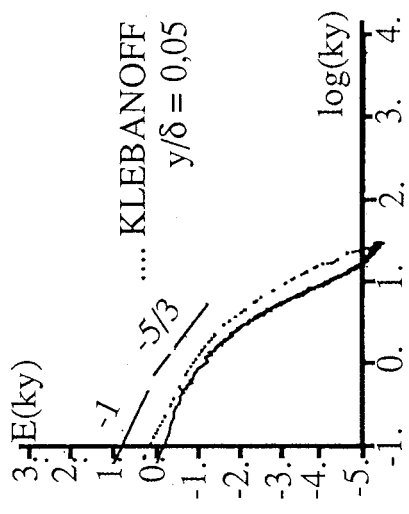


Figure 3-14 Spectre d'énergie de la fluctuation longitudinale ($x = 955 \text{ mm}$)

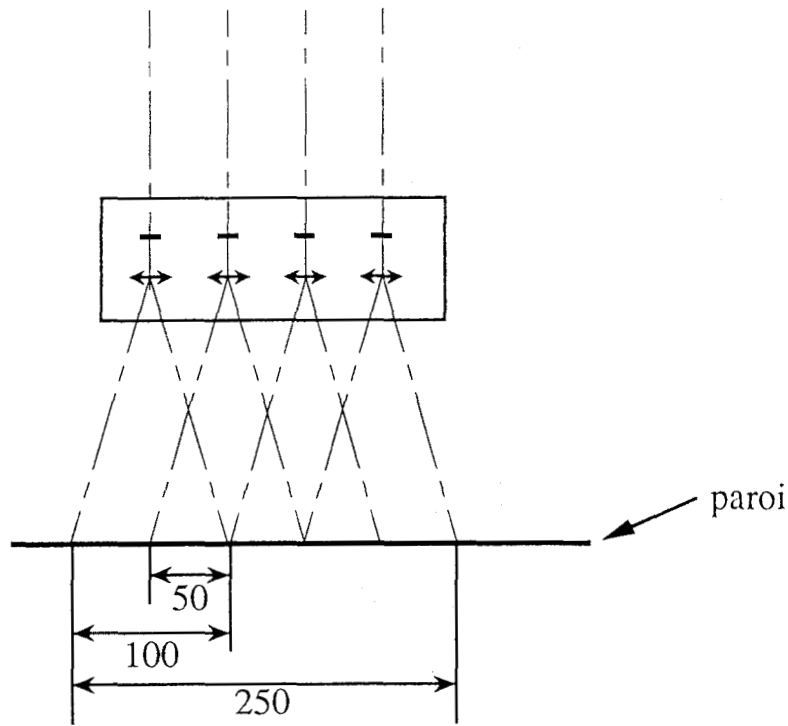


$U_e = 12,6 \text{ m/s}$

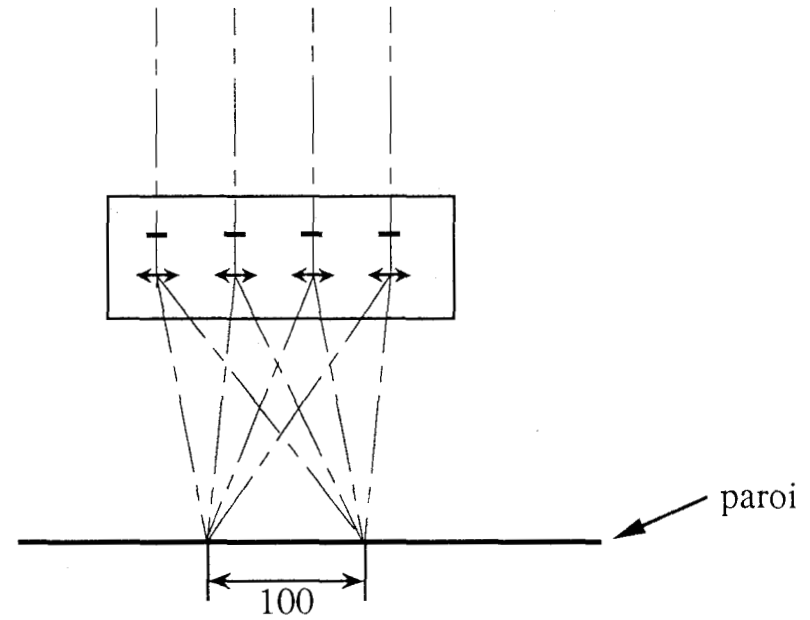
$U_e = 22 \text{ m/s}$

$U_e = 27,4 \text{ m/s}$

Figure 3-15 Spectres d'énergie de la fluctuation longitudinale ($x = 2555\text{mm}$)



Cadrage large: plans lasers décalés



Cadrage serré: plans lasers superposés

Figure 4-1 Différents arrangements des plans de lumière issus des quatre cavités laser

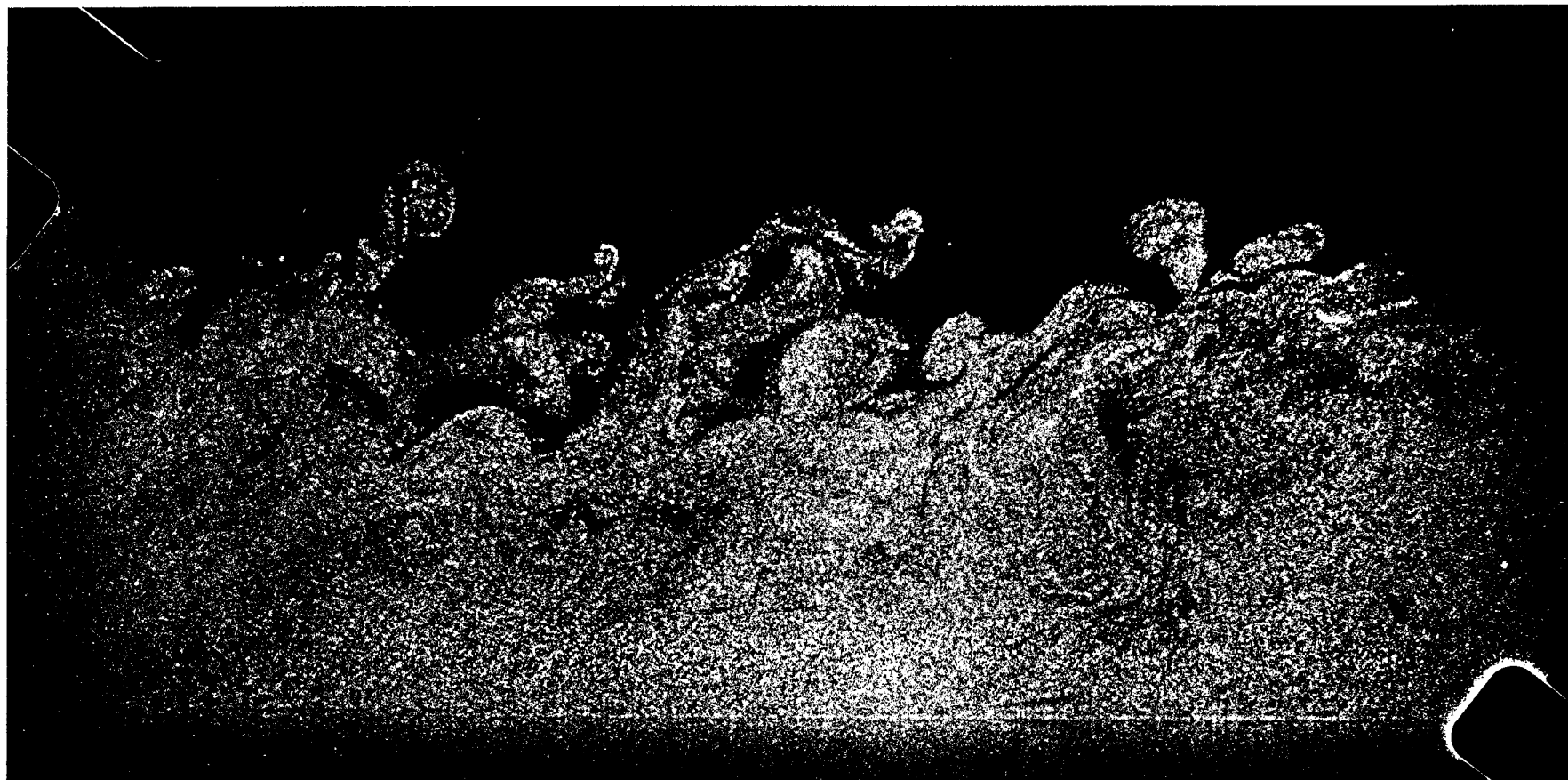


Figure 4-2 Exemple de cliché réalisé avec une simple injection de fumée

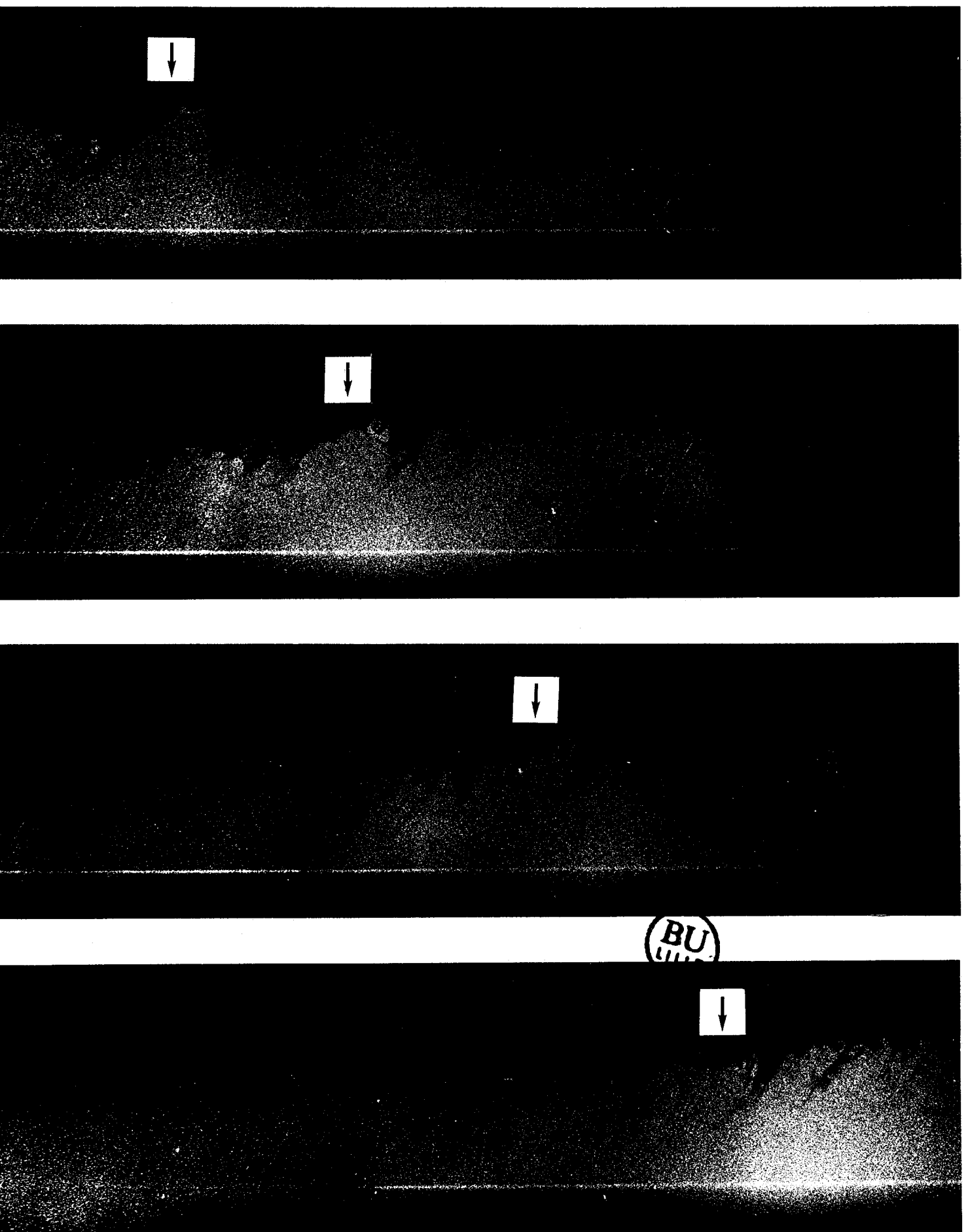


Figure 4-3 Grosse structure évolutive à la frontière de la couche limite
 $\delta t = 2,4 \text{ ms} - U_e = 22 \text{ m/s}$

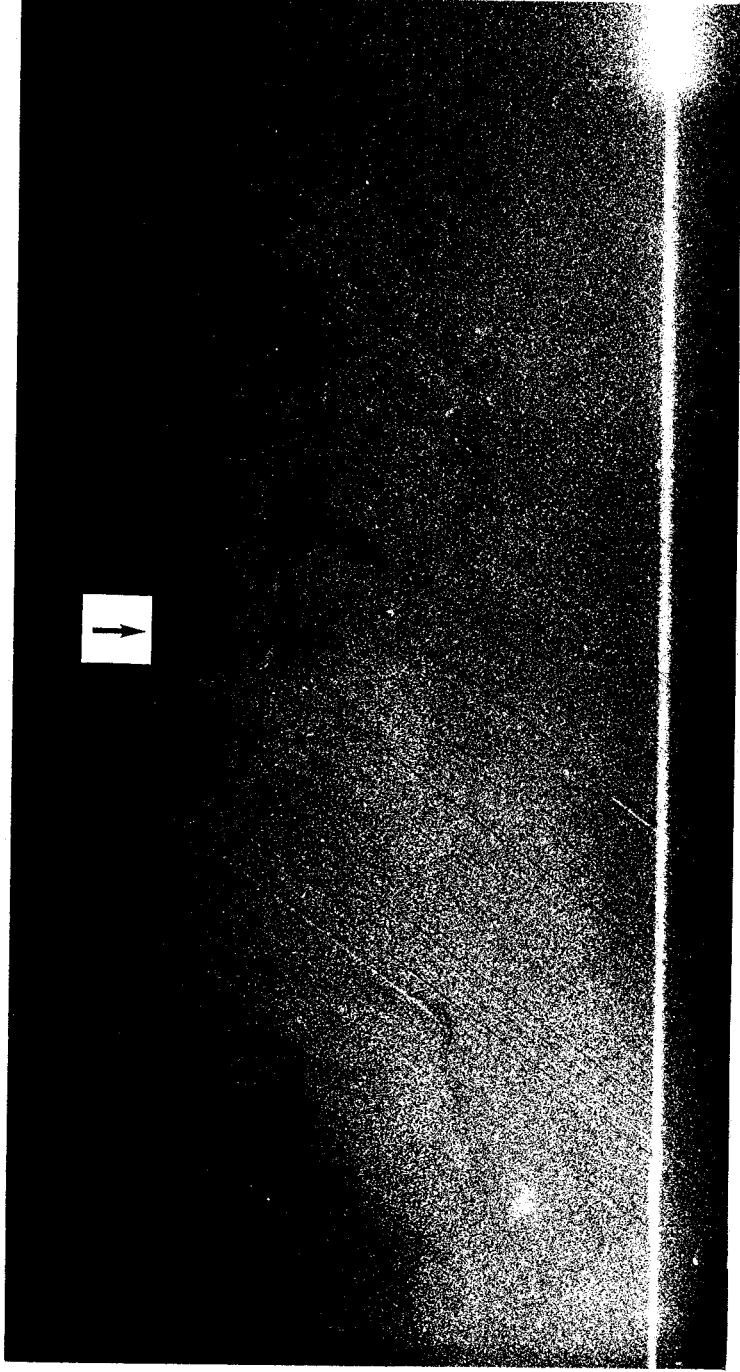
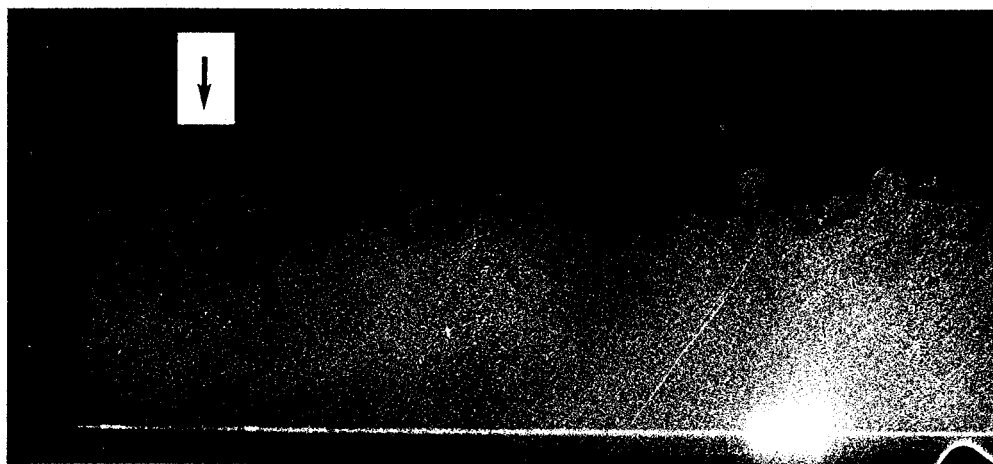


Figure 4-4 Tourbillon typique, $Re\theta = 3515$



BU
LILLE

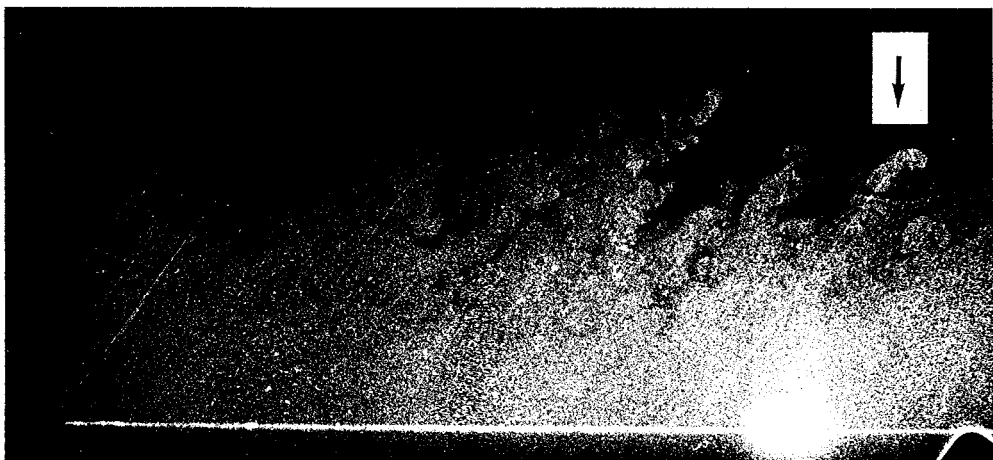
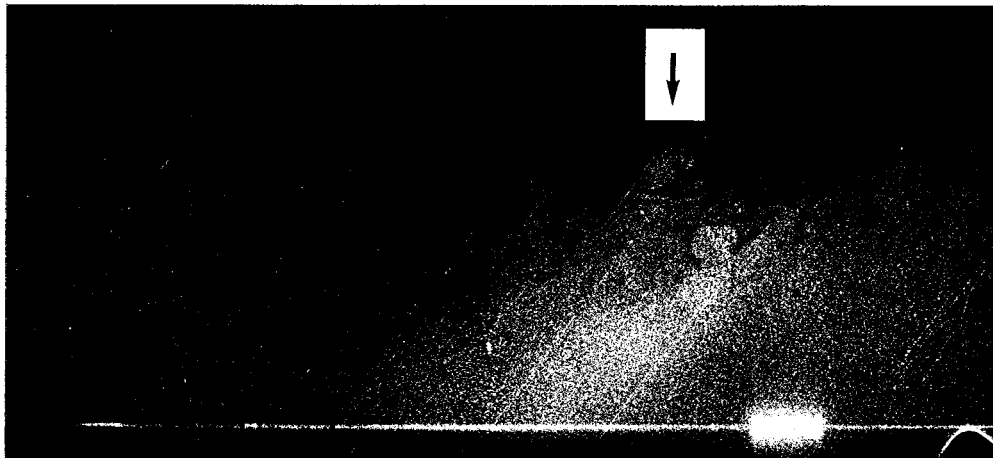
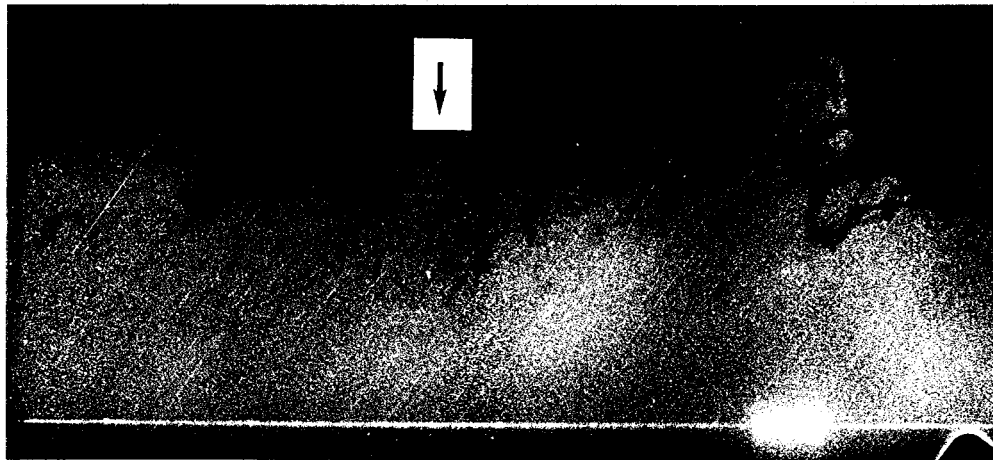


Figure 4-5 Evolution d'un tourbillon typique
 $\delta t = 1,5 \text{ ms}$ - $Re_{\theta} = 6278$

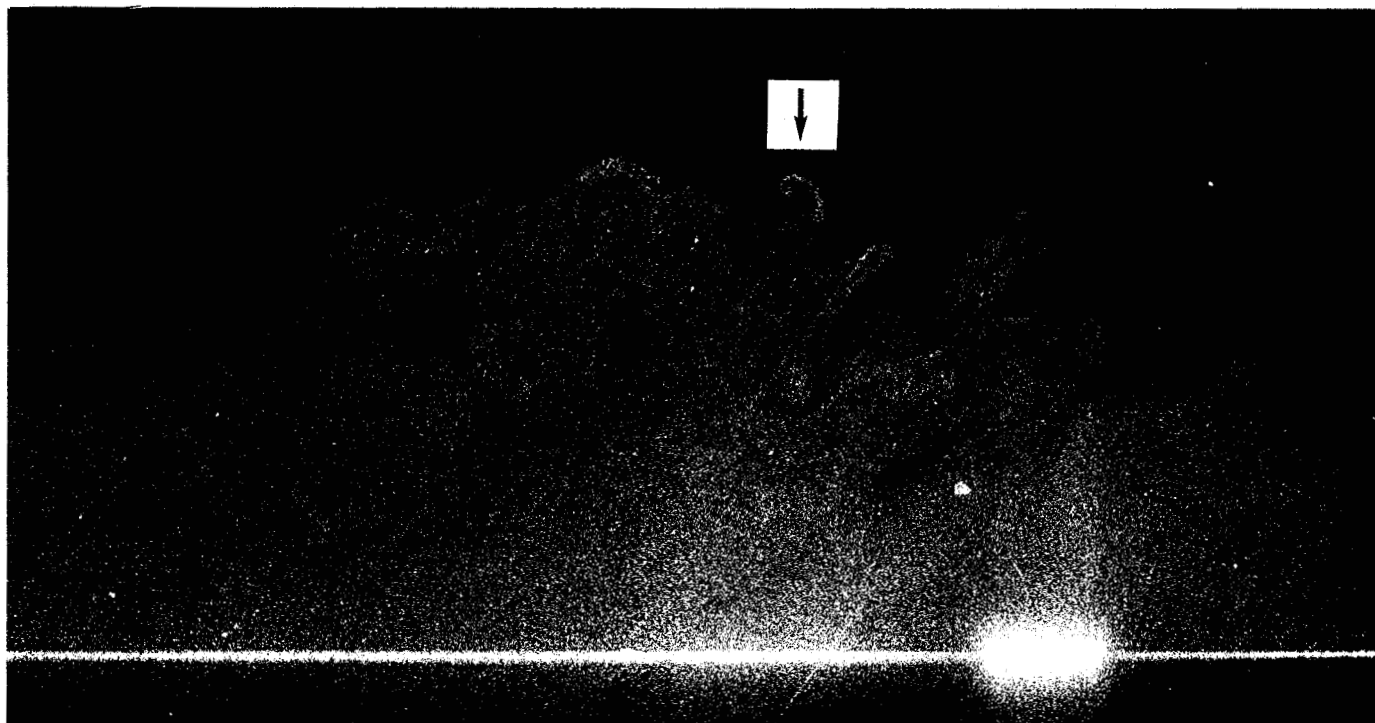


Figure 4-6 Structure contra-rotative, $Re_{\theta} = 3515$



Figure 4-7 Front montant, $Re_{\theta} = 3515$

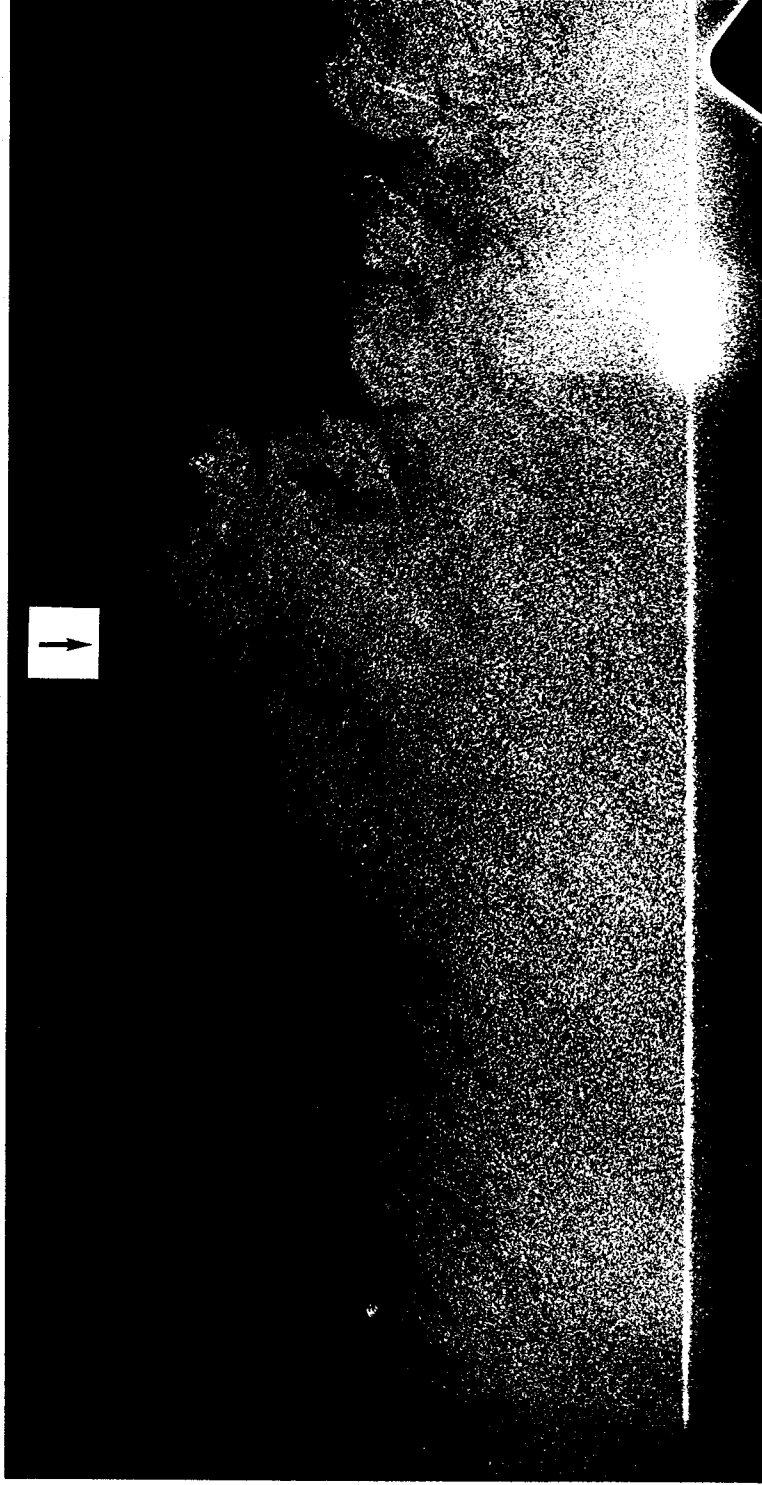


Figure 4-8 Structure géante, $Re\theta = 6278$

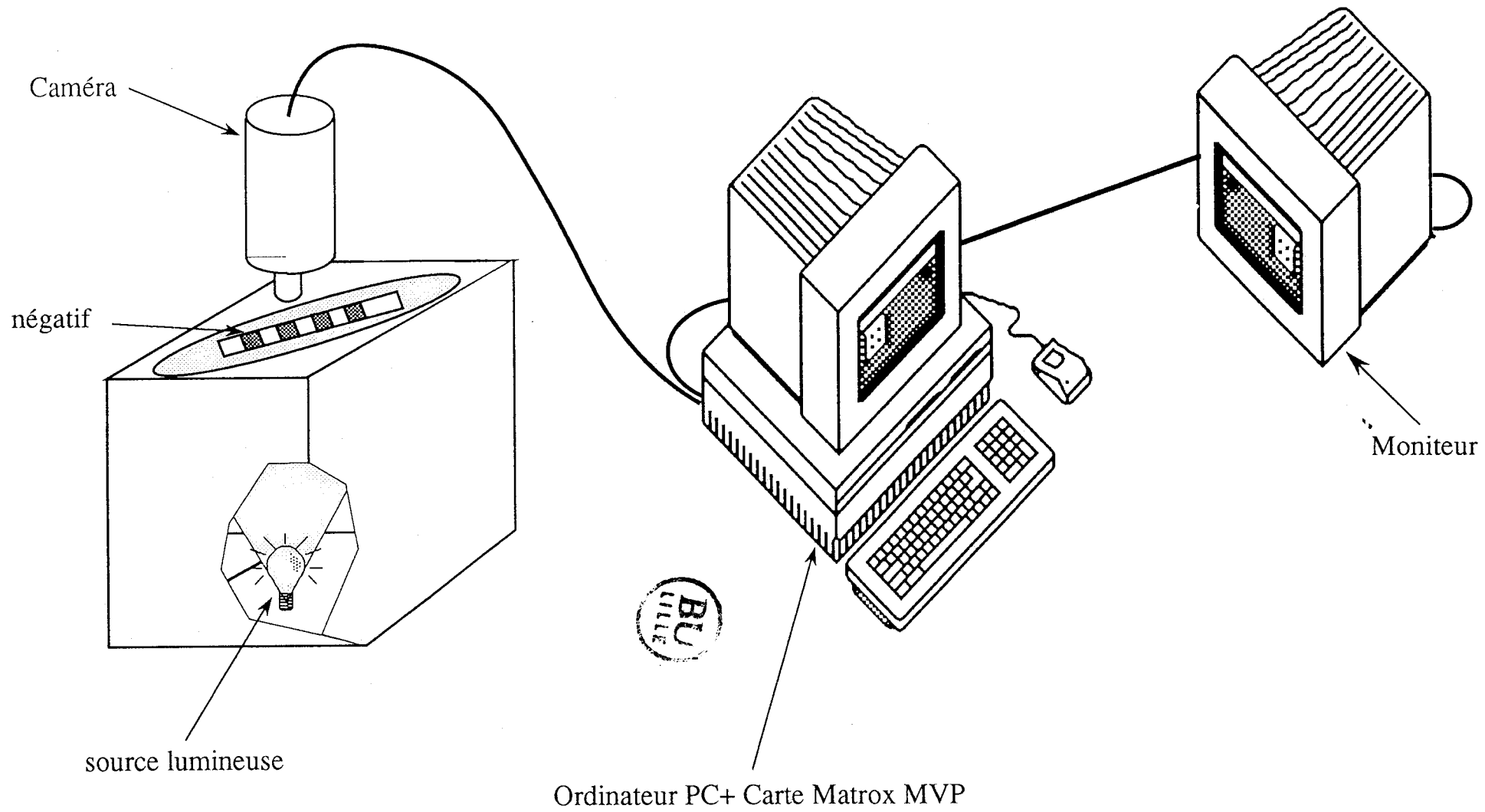


Figure 4-9 Schéma simplifié du système de traitement d'image



Image numérisée



Film original

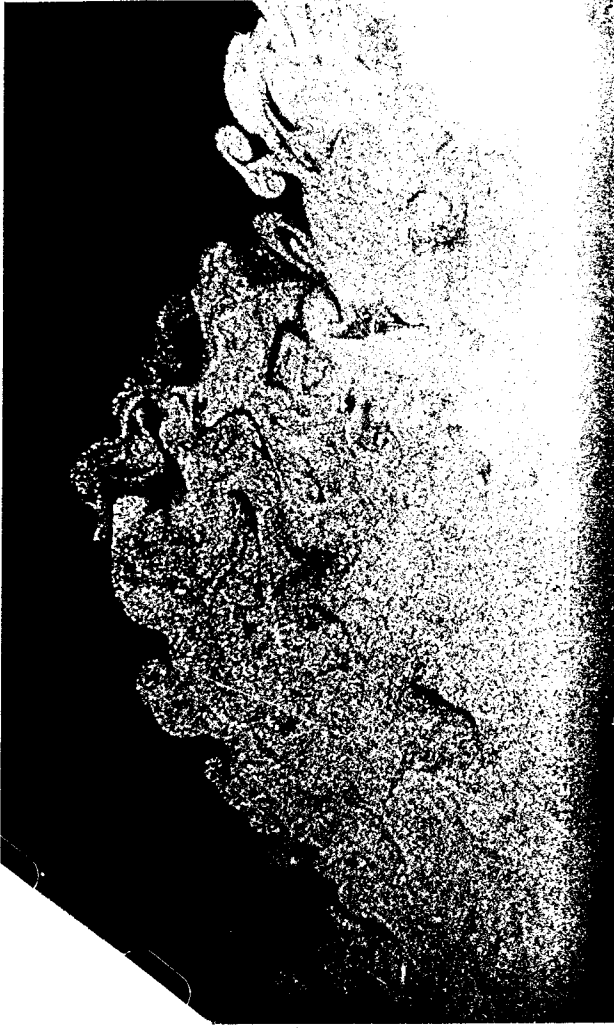


Figure 4-10 Exemple d'image numérisée sur la carte Matrox MVP

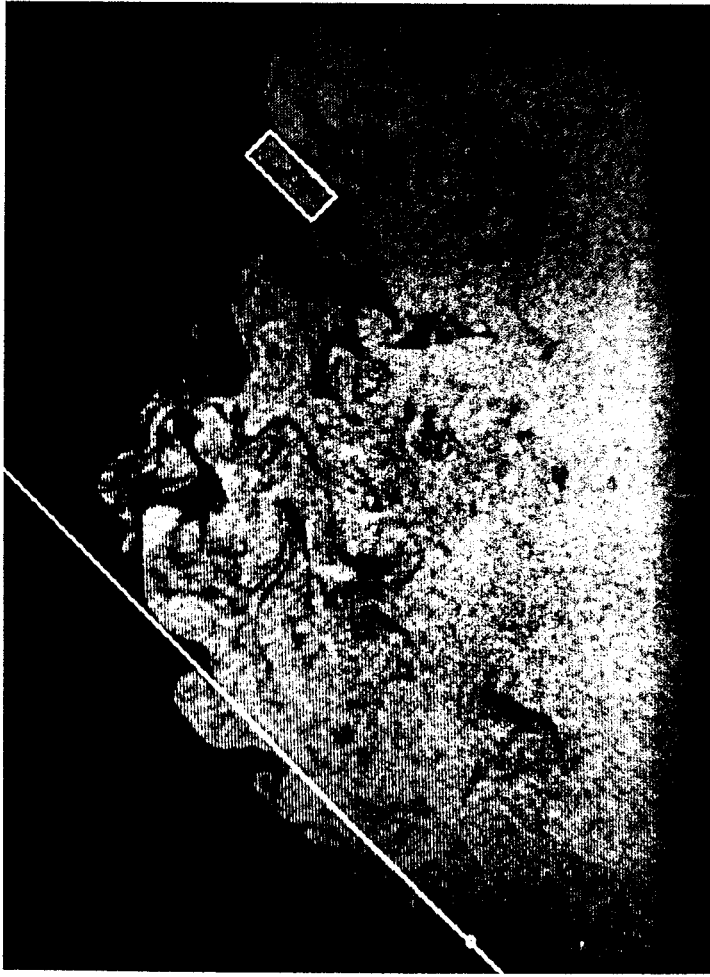
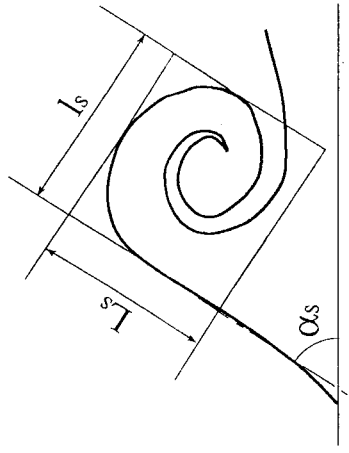
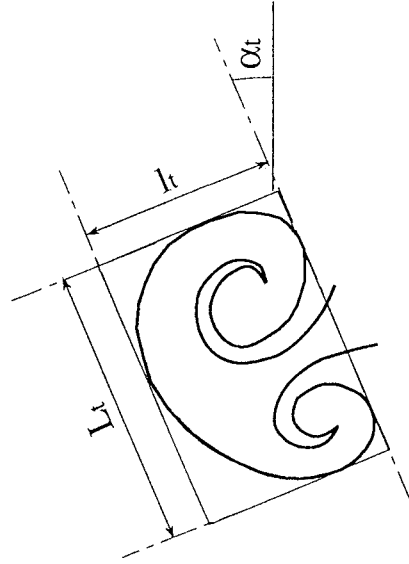
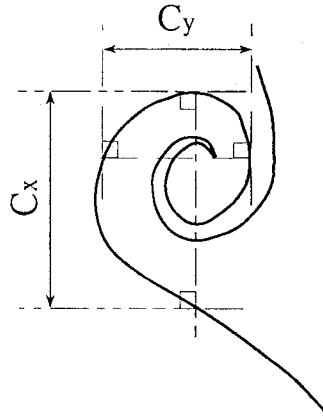


Figure 4-11 Exemples de traitement d'images numérisées



tourbillon simple



tourbillon typique

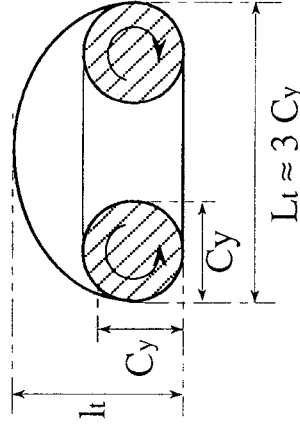
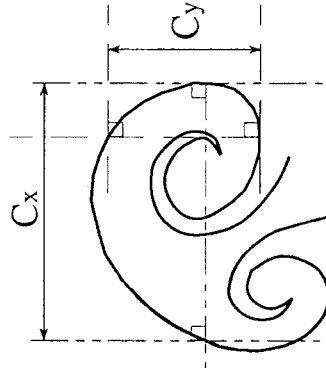


schéma simplifié



dimensions mesurées
au cours de l'étude

dimensions mesurées
par FALCO

Figure 4-12 Dimensions des tourbillons mesurées par FALCO [27] et dans la présente étude

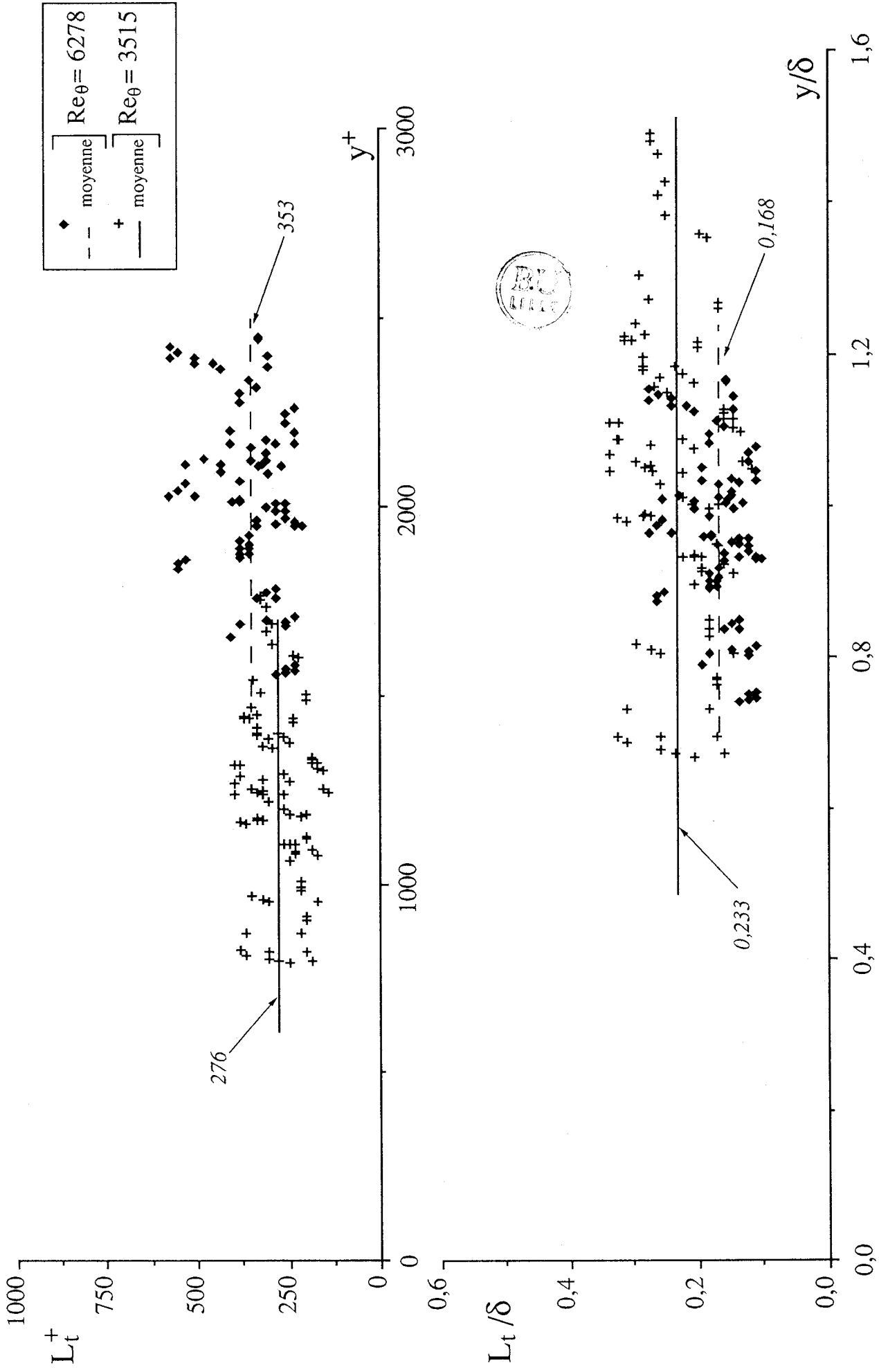


Figure 4-13 Dimension L_t des tourbillons typiques en fonction de leur position dans la zone externe de la couche limite

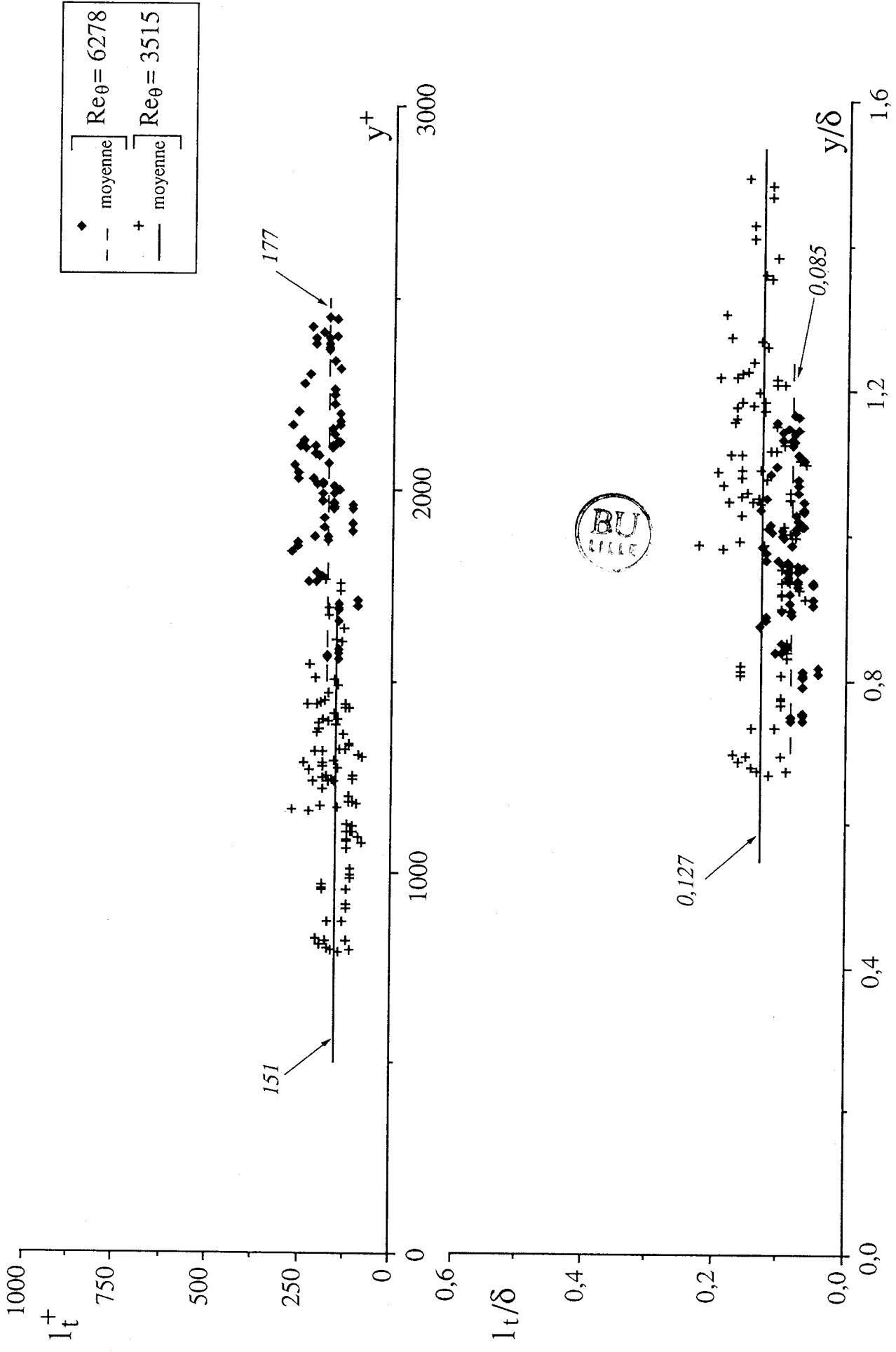


Figure 4-14 Dimension l_t des tourbillons typiques en fonction de leur position dans la zone externe de la couche limite

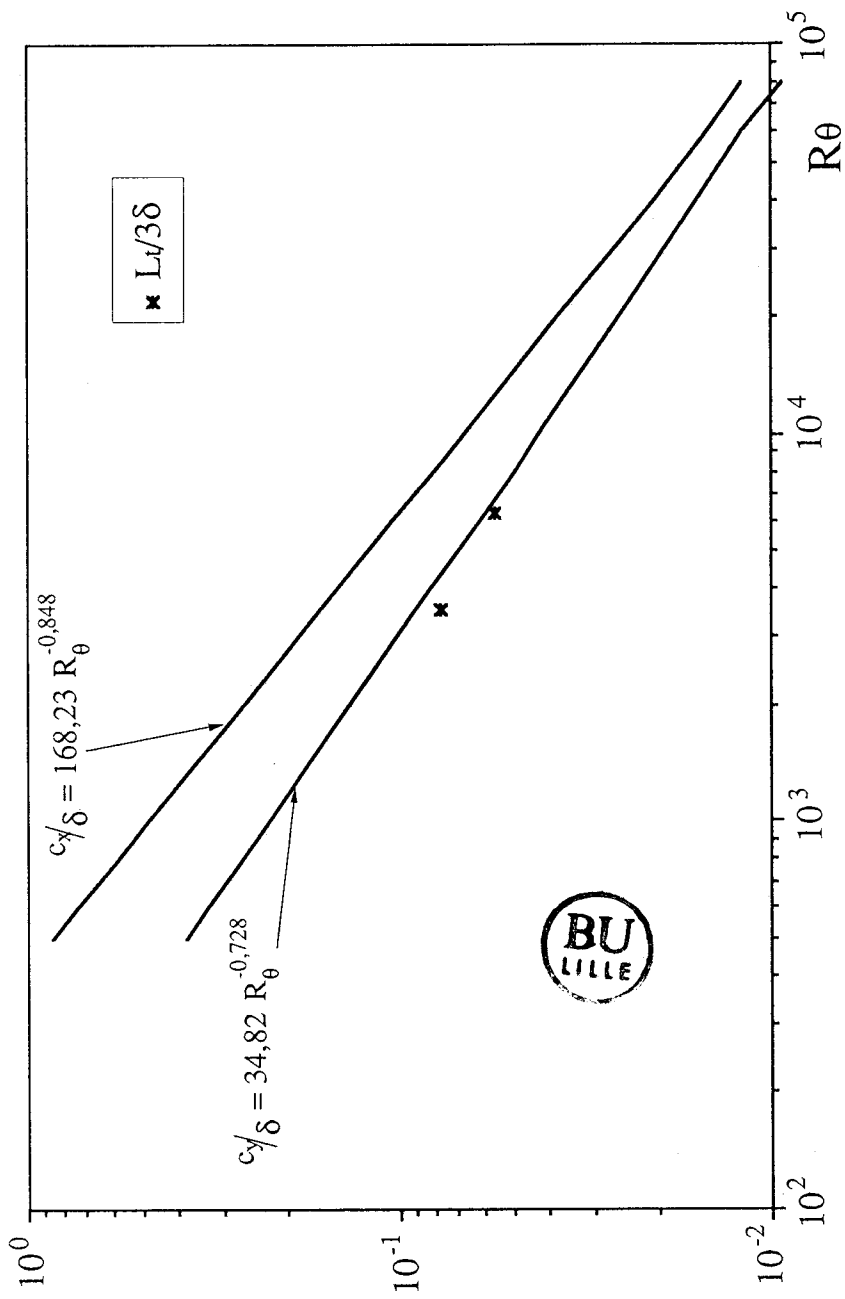


Figure 4-15 Comparaison des valeurs de $L_t/3$ avec les courbes de FALCO extraites de [26]

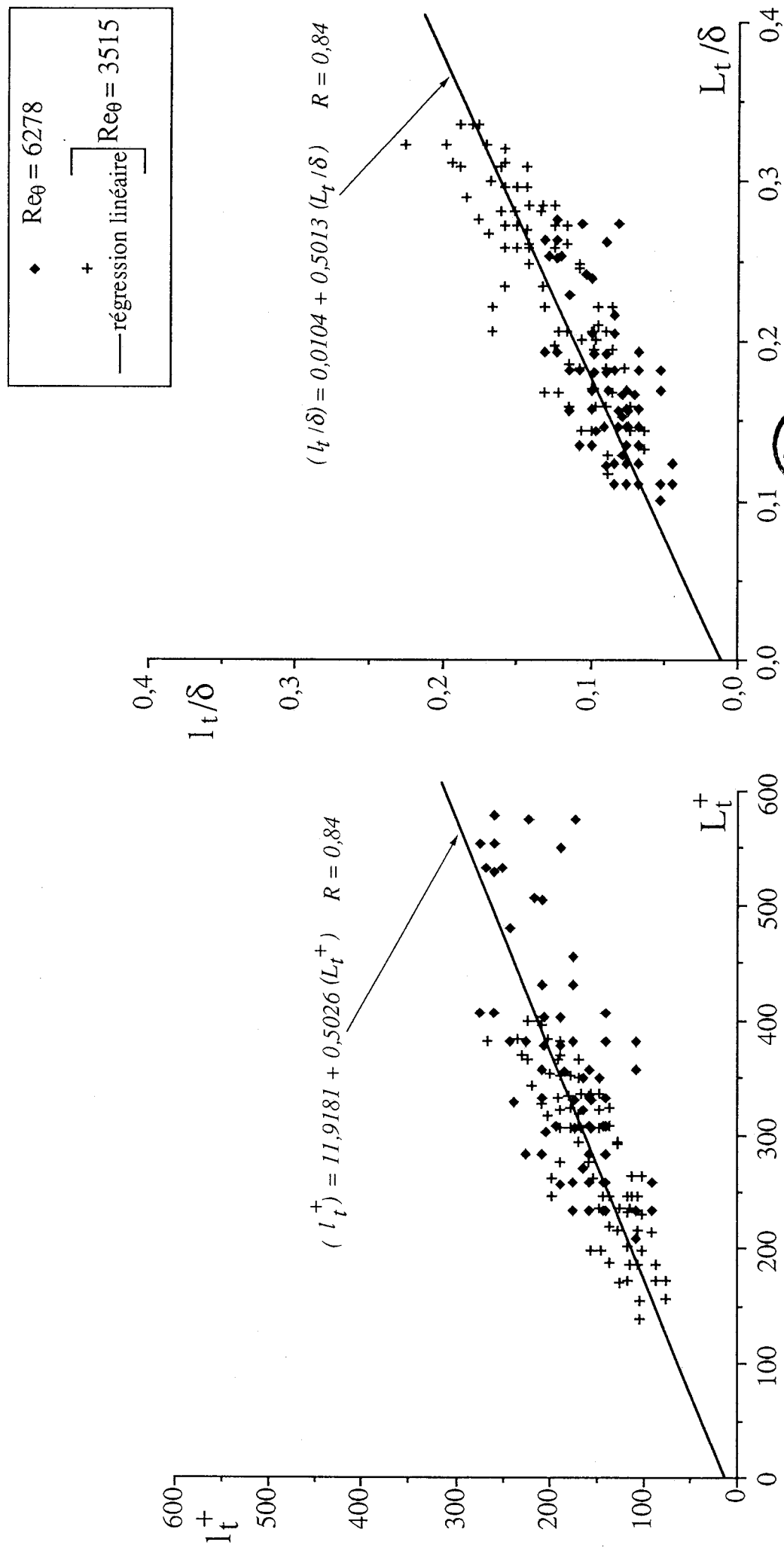


Figure 4-16 Evolutions respectives des dimensions des tourbillons typiques

▨ $Re_{\theta} = 3515$
 ▩ $Re_{\theta} = 6278$

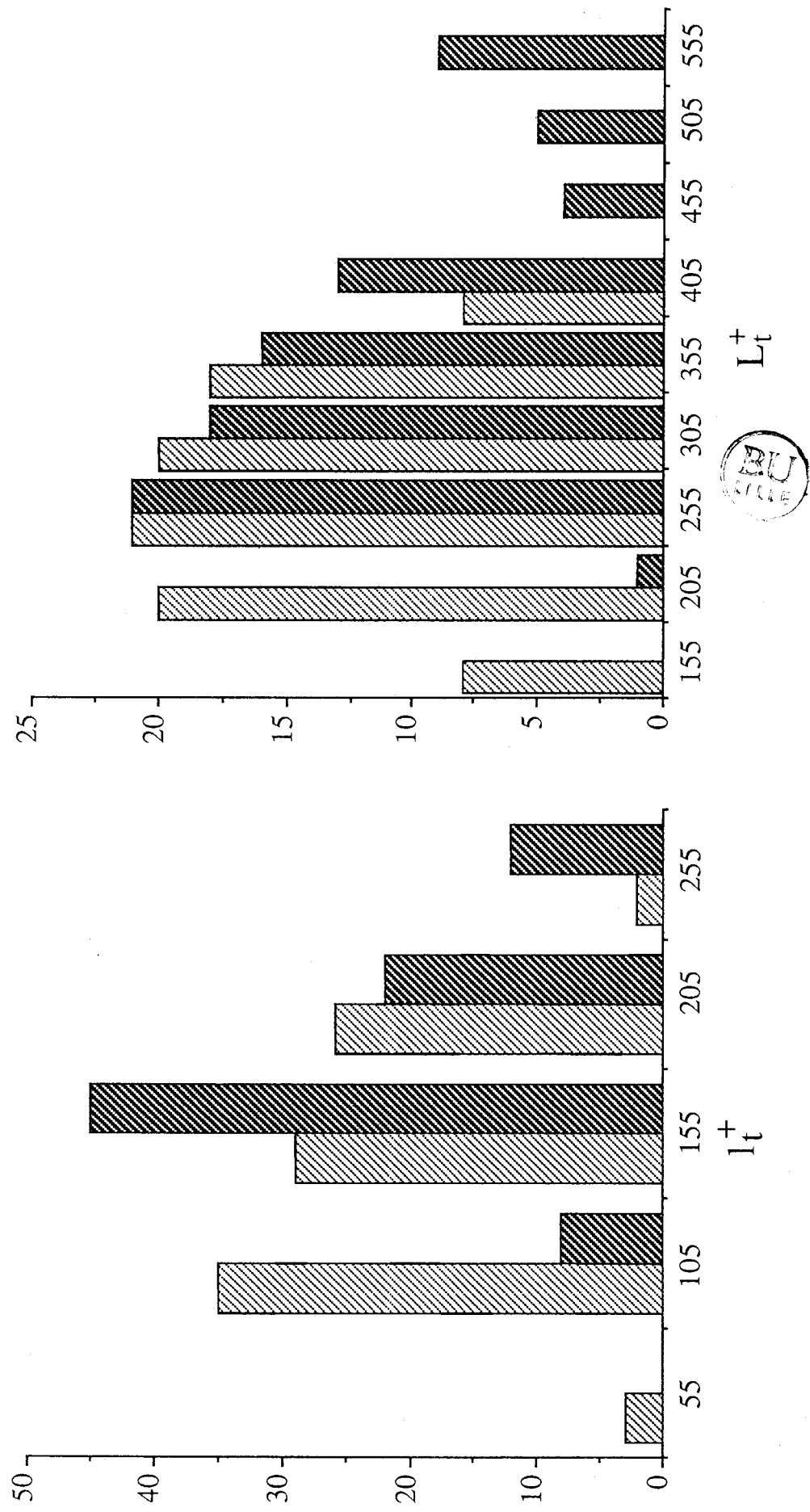


Figure 4-17 Histogrammes des dimensions des tourbillons typiques dans la zone externe de la couche limite

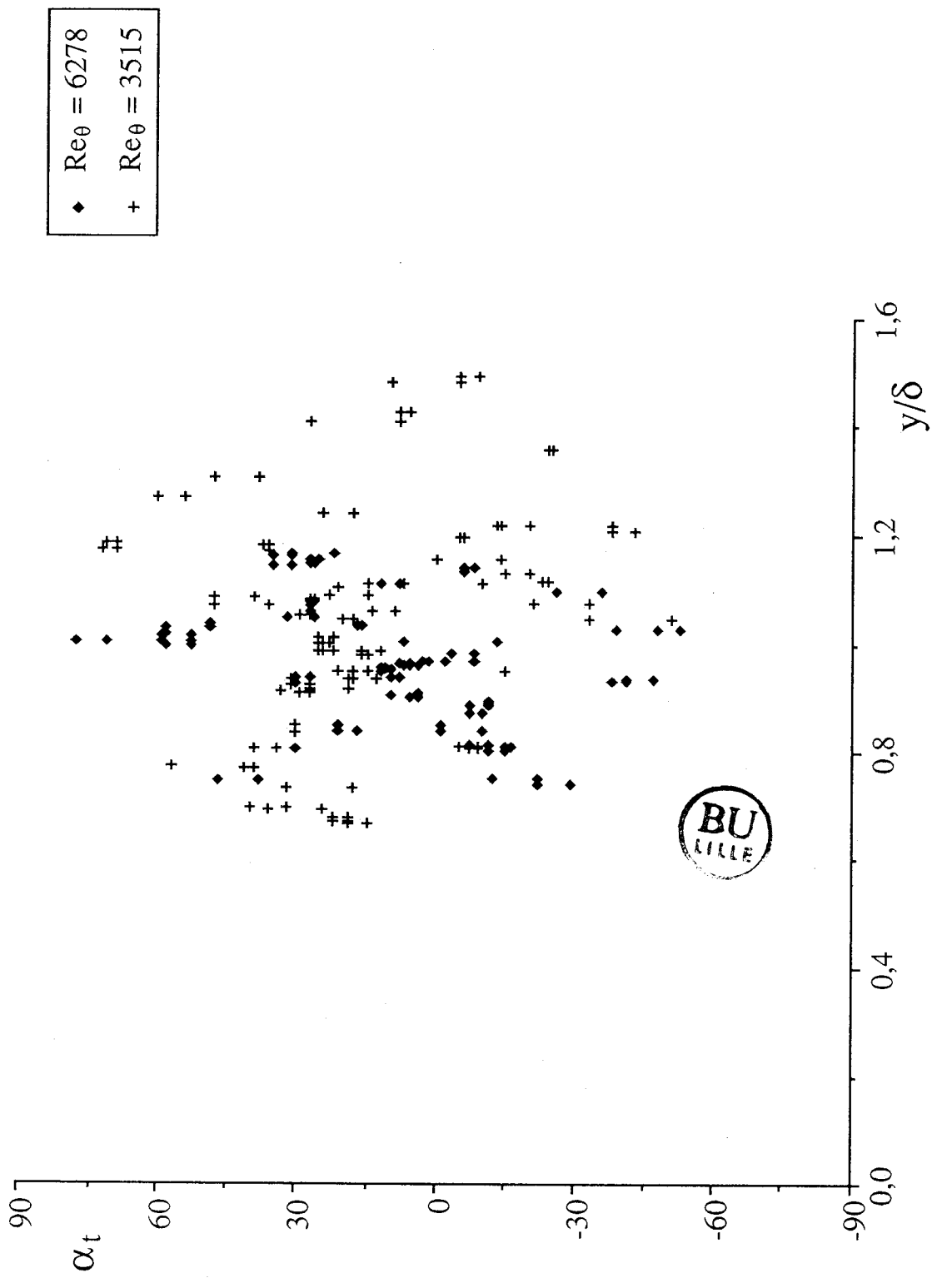


Figure 4-18 Angle des tourbillons typiques en fonction de leur position dans la zone externe de la couche limite

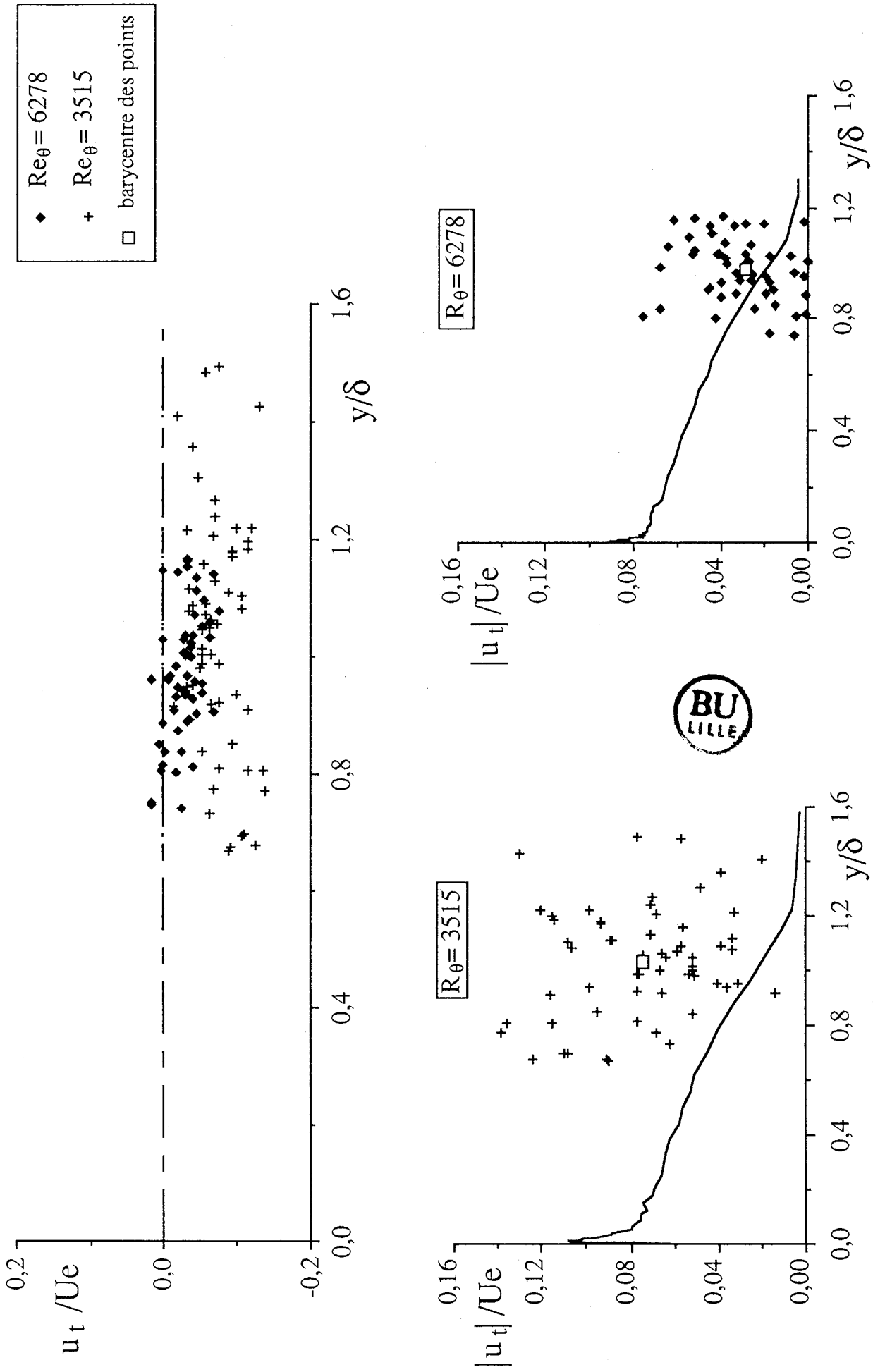


Figure 4-19 Vitesse longitudinale des tourbillons typiques en fonction de leur position dans la zone externe de la couche limite

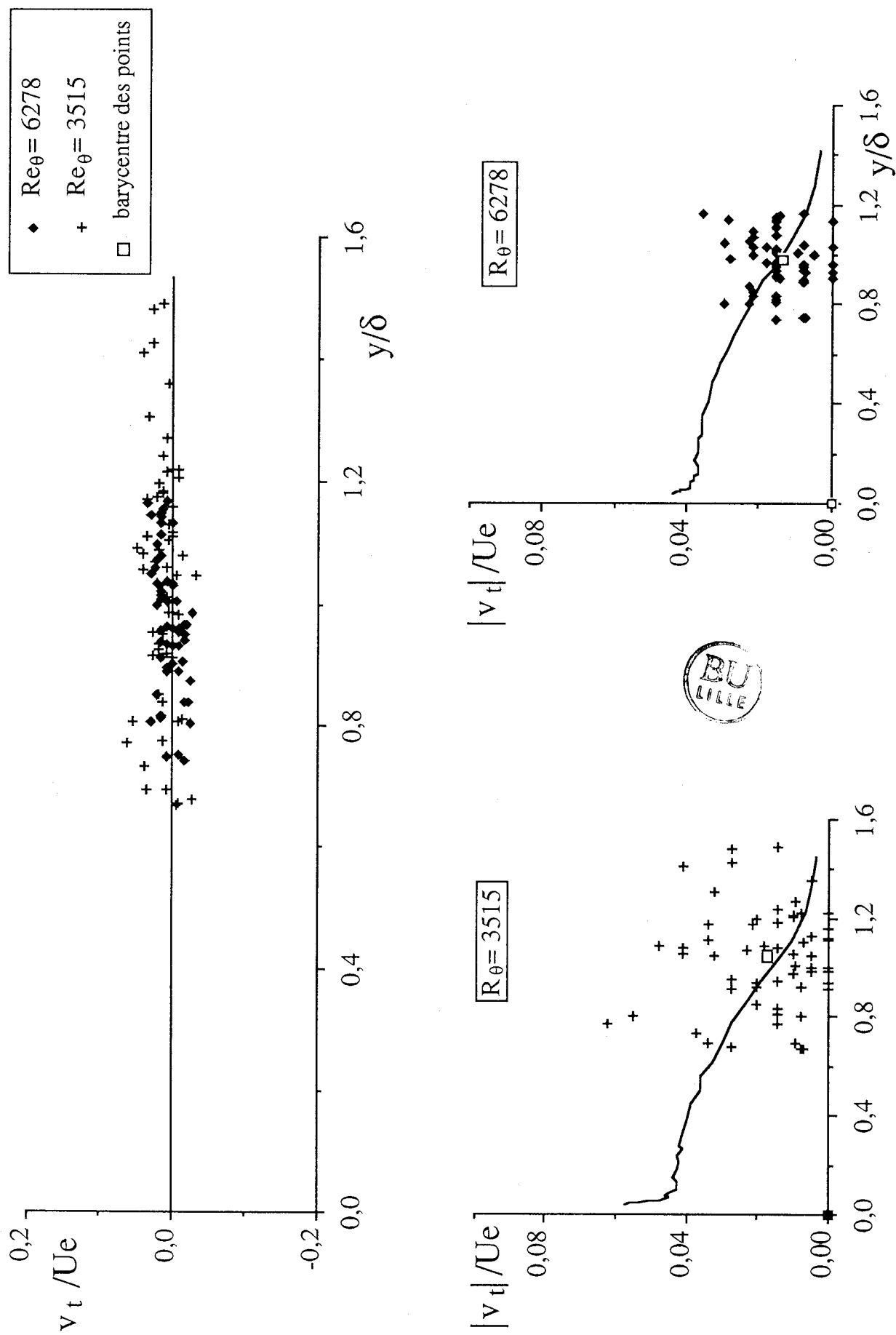


Figure 4-20 Vitesse normale des tourbillons typiques en fonction de leur position dans la zone externe de la couche limite

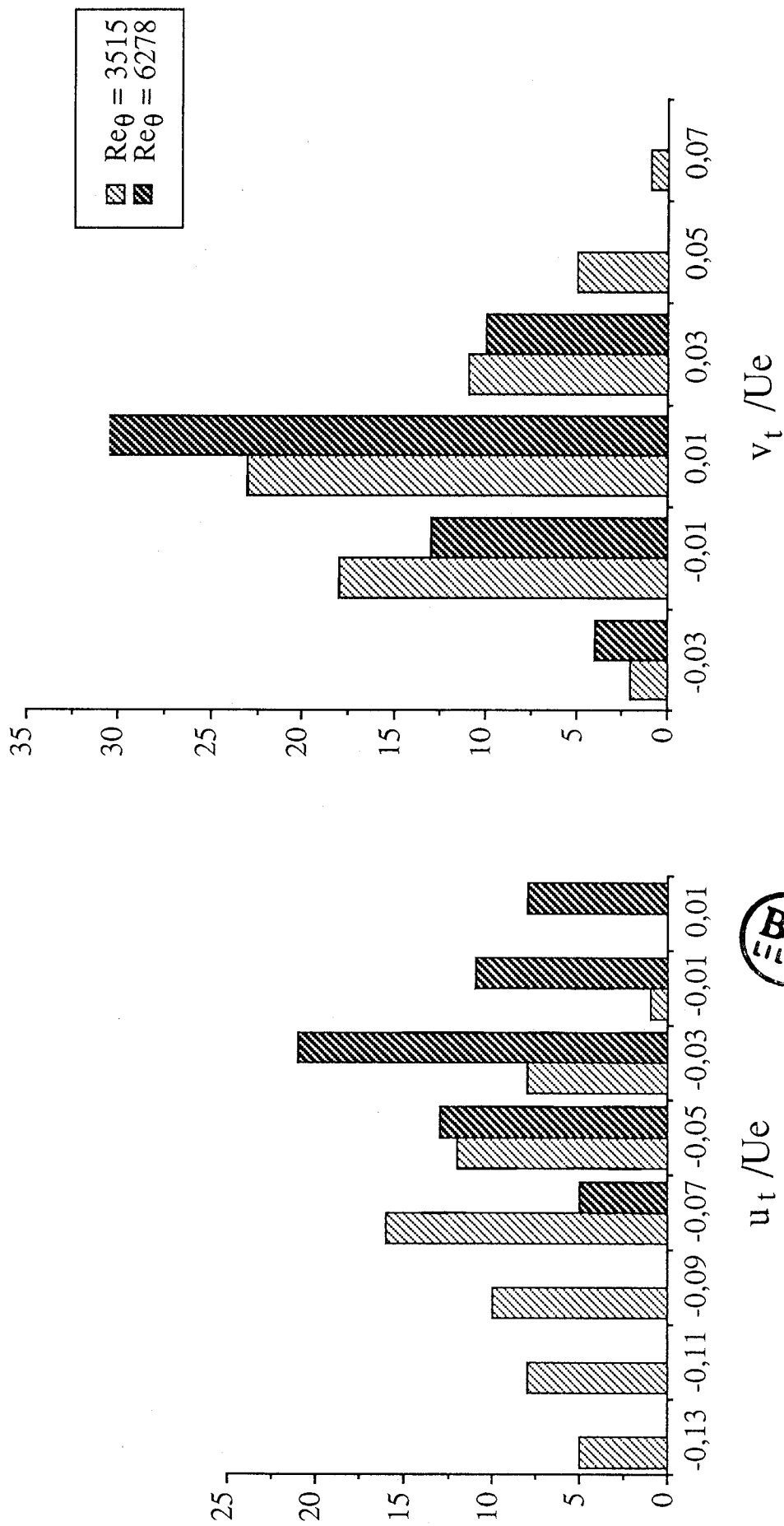


Figure 4-21 Histogrammes des vitesses des tourbillons typiques dans la zone externe de la couche limite

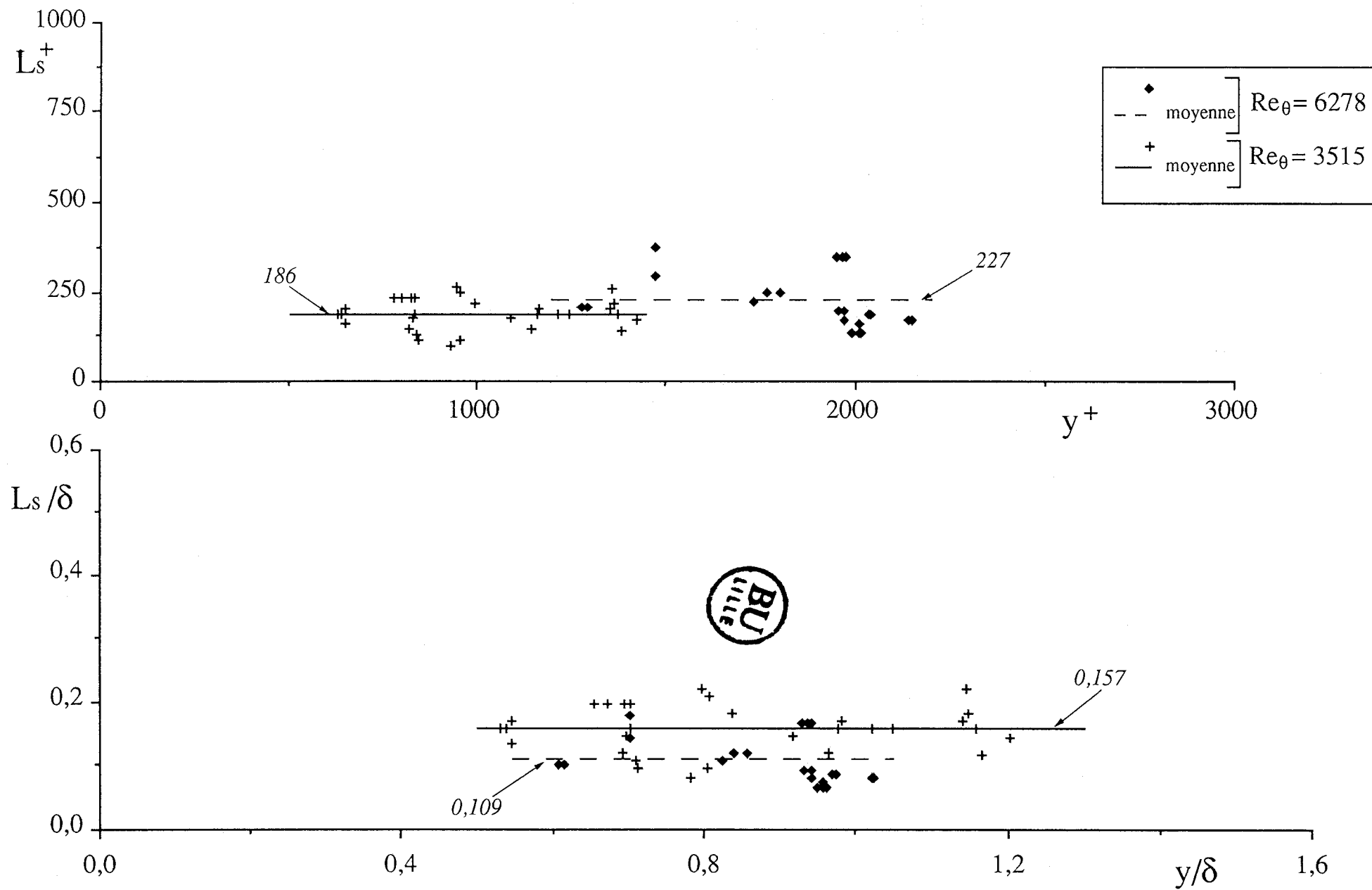


Figure 4-22 Dimension L_s des tourbillons simples en fonction de leur position dans la zone externe de la couche limite

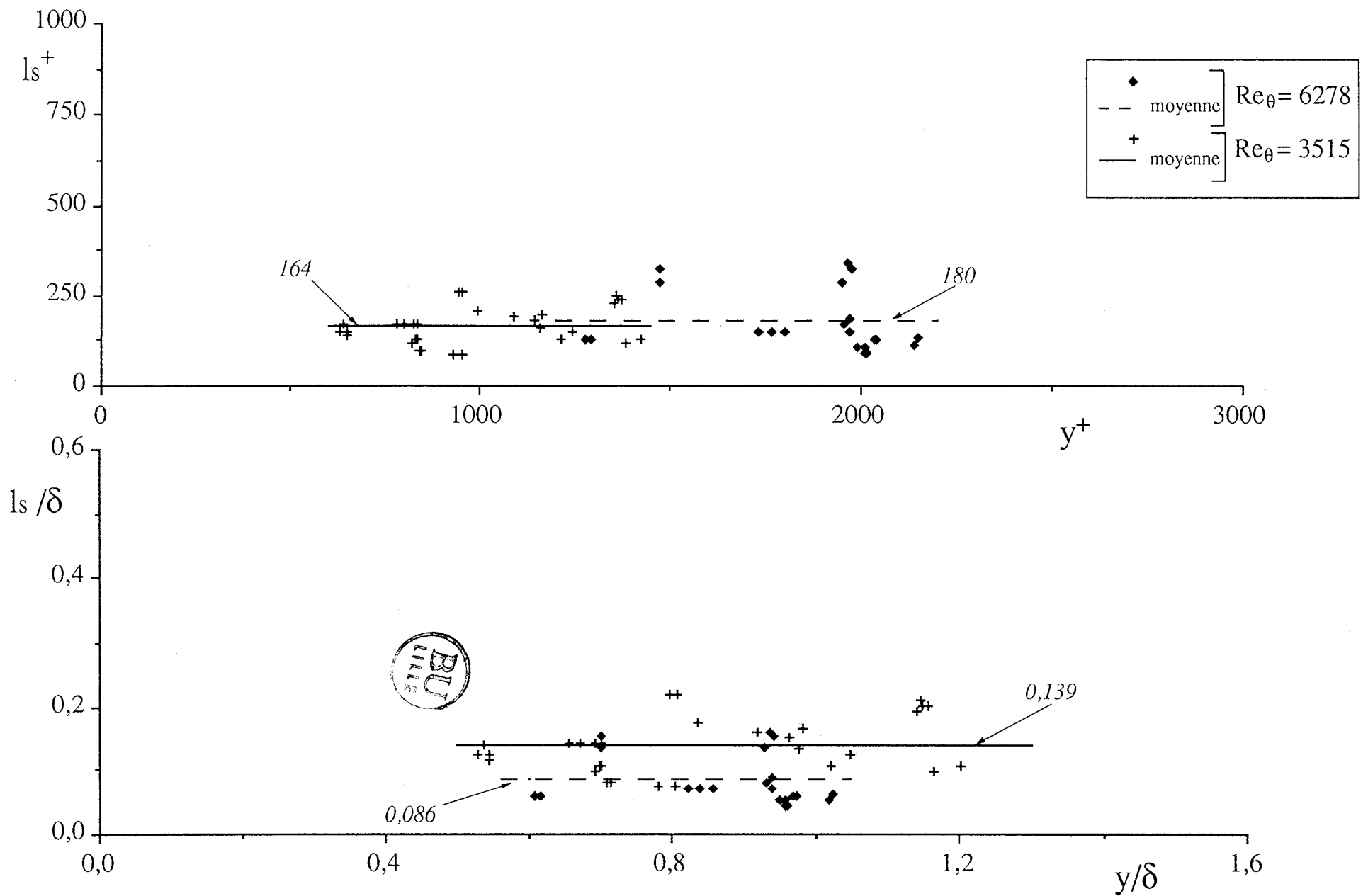


Figure 4-23 Dimension ls des tourbillons simples en fonction de leur position dans la zone externe de la couche limite

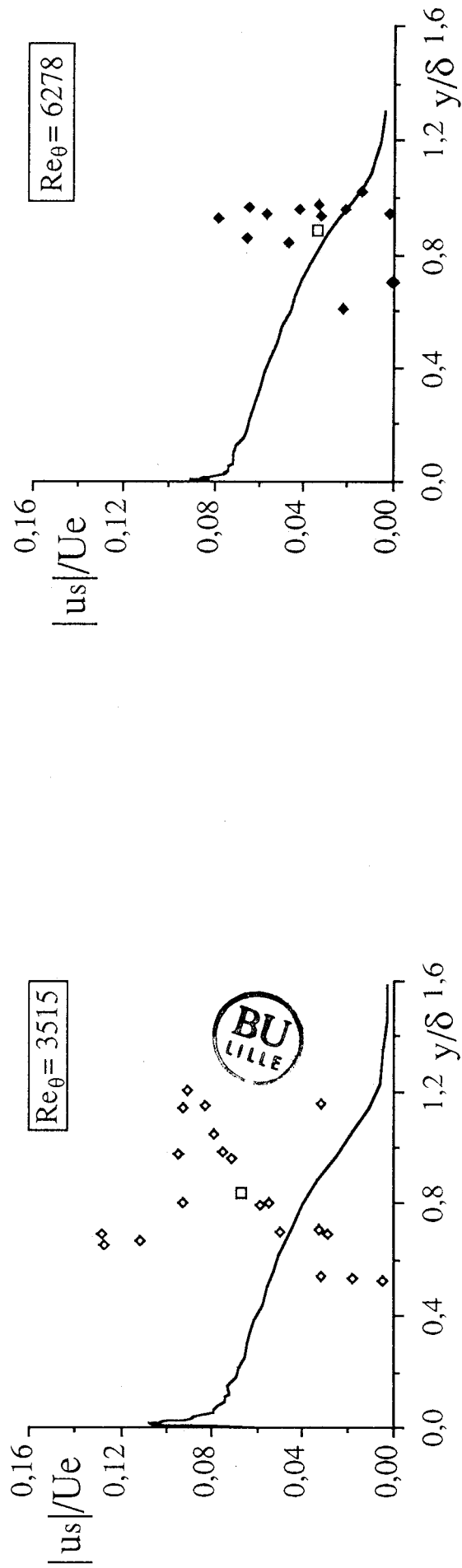
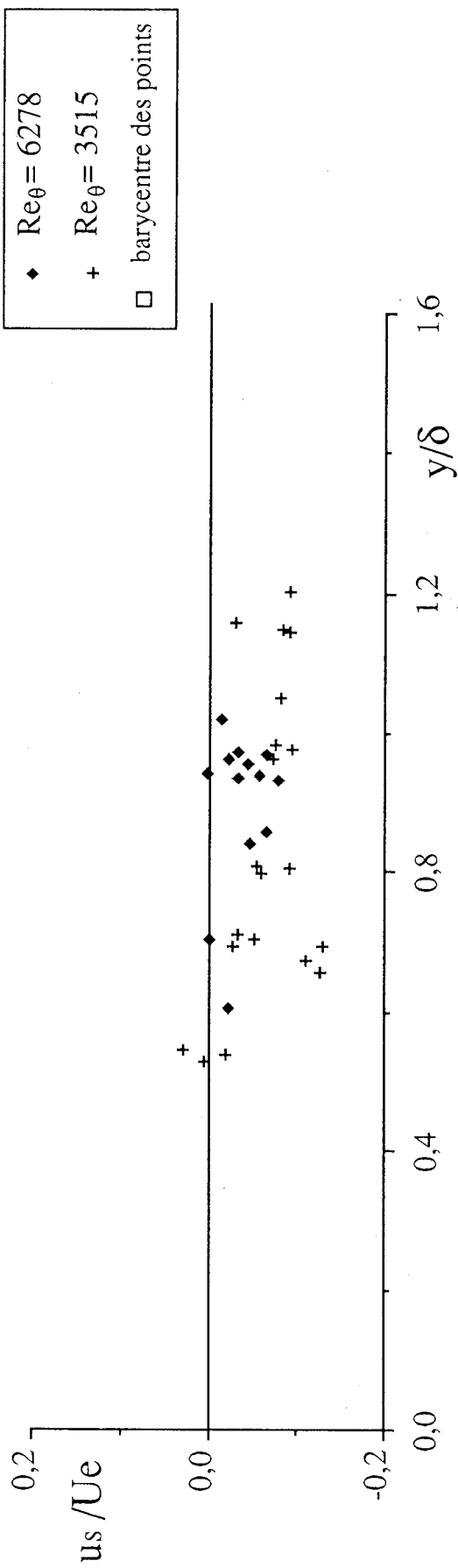


Figure 4-24 Vitesse longitudinale des tourbillons simples en fonction de leur position dans la zone externe de la couche limite

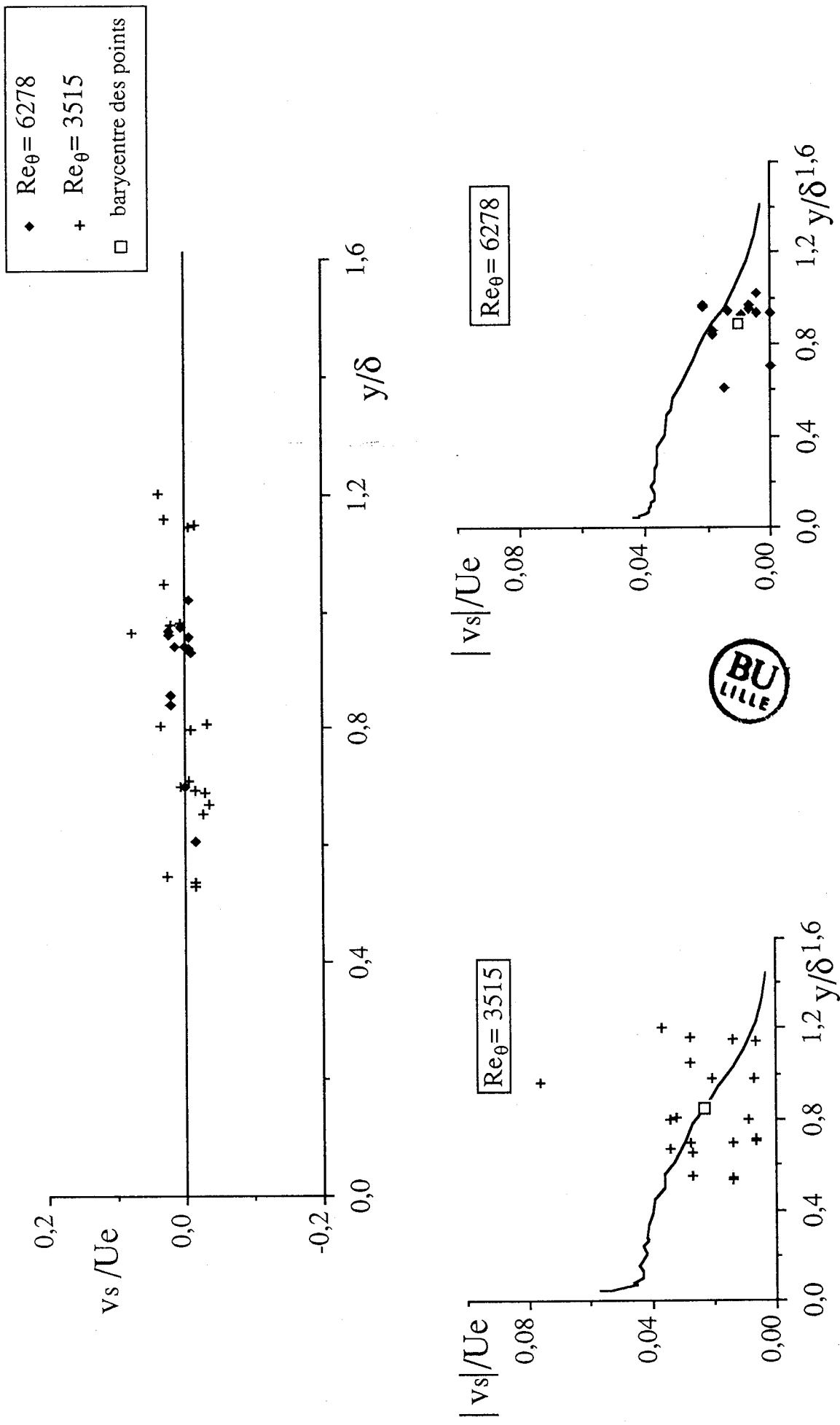


Figure 4-25 Vitesse normale des tourbillons simples en fonction de leur position dans la zone externe de la couche limite

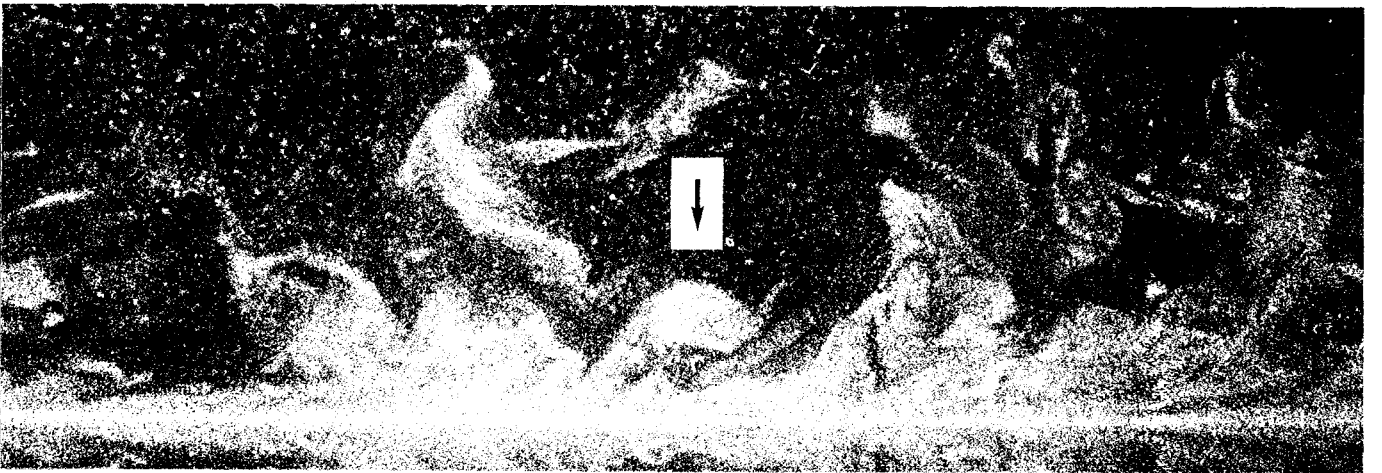
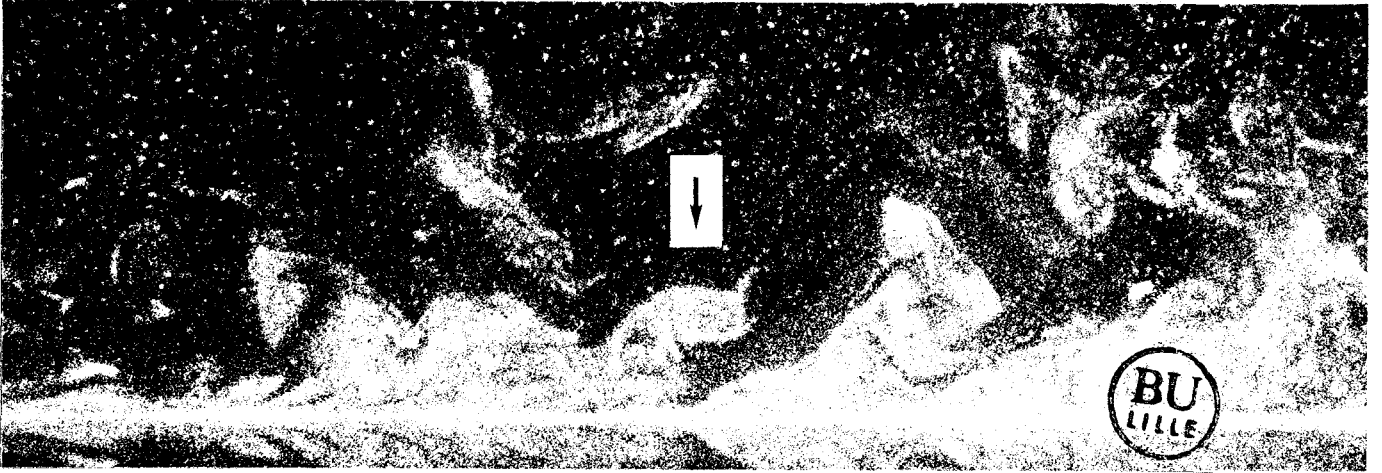
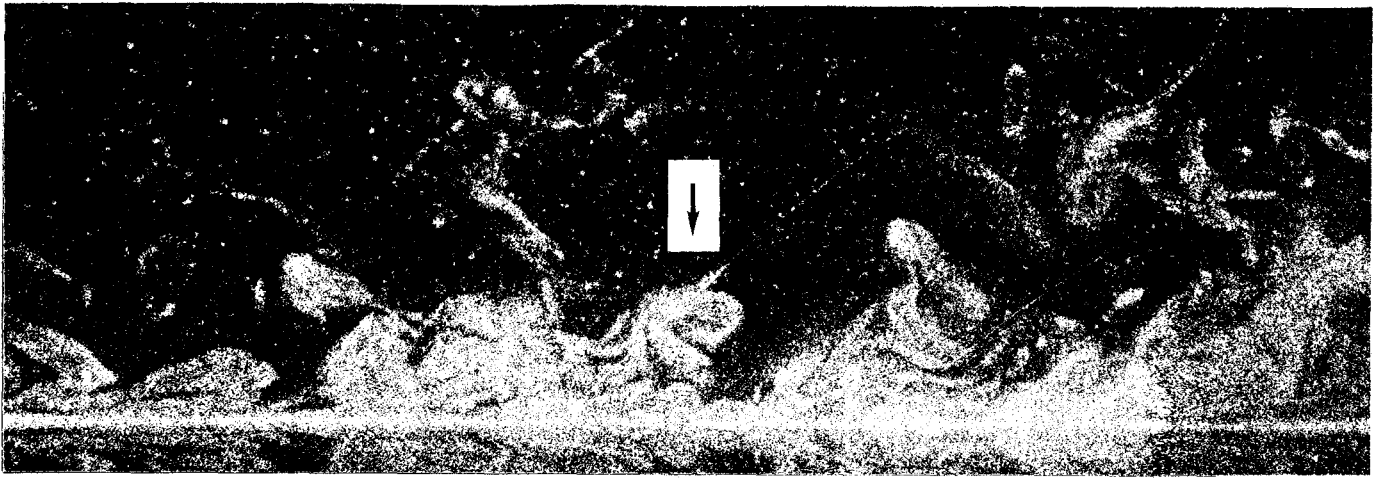


Figure 4-26 Exemple de tourbillon typique - $\Delta t^+ = 18$

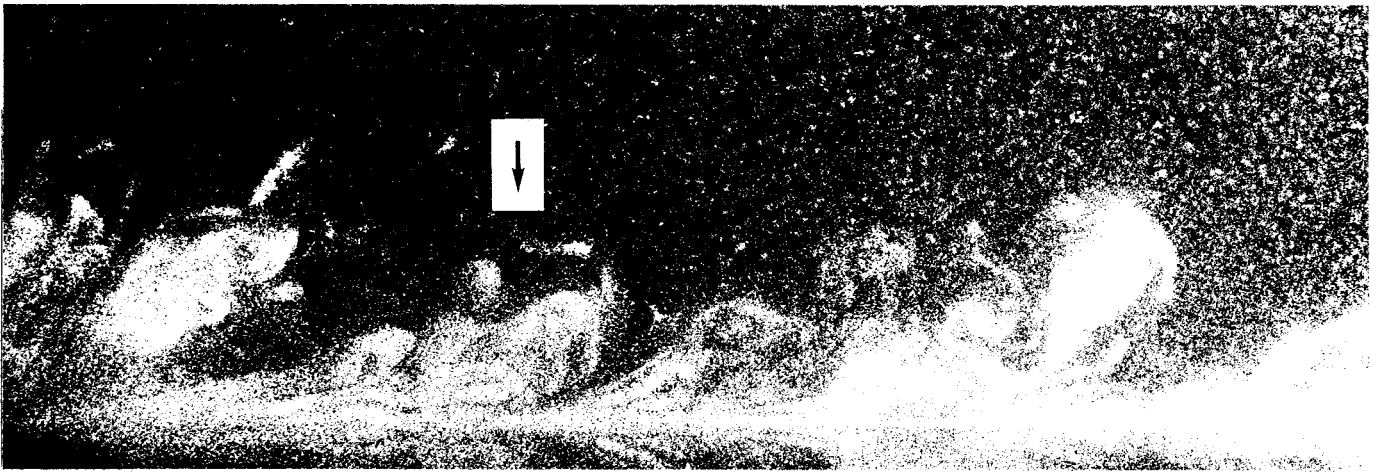


Figure 4-27 Exemple de tourbillon typique - $\Delta t^+ = 18$

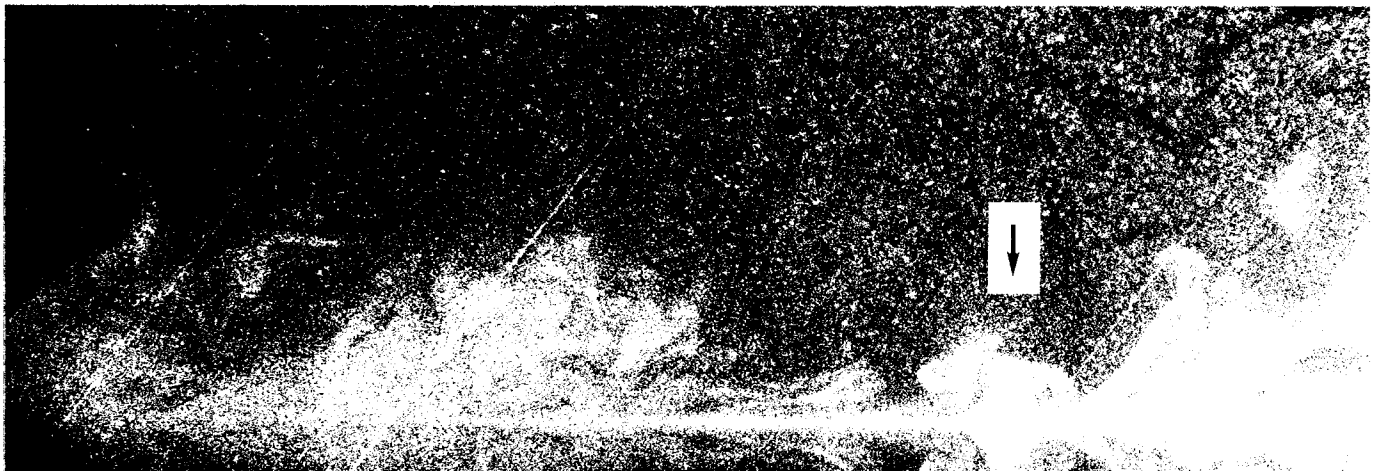
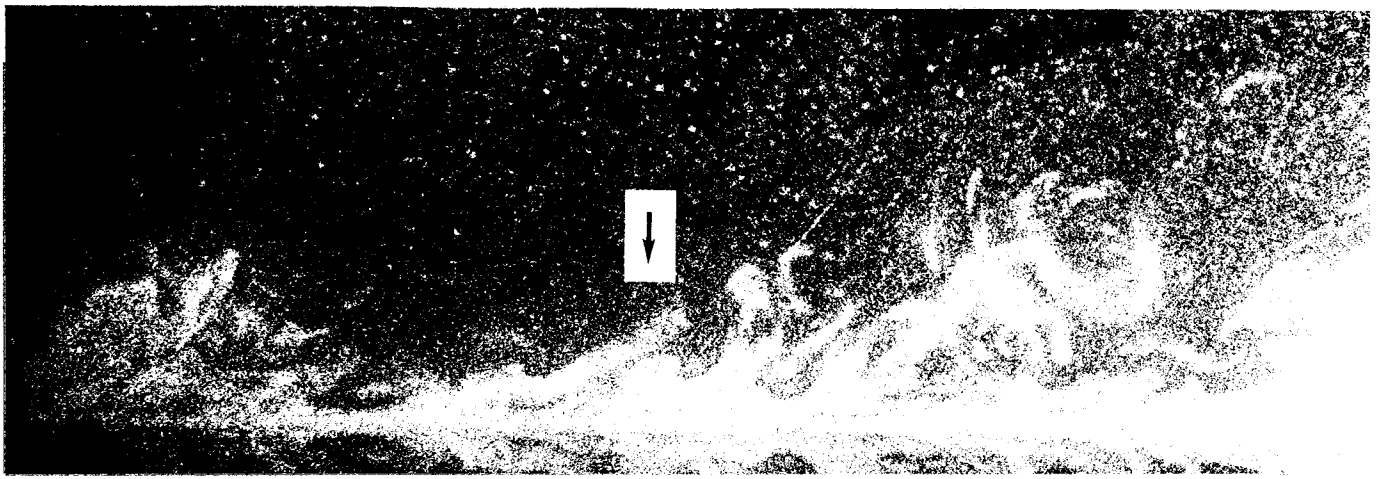


Figure 4-28 Exemple de tourbillon typique - $\Delta t^+ = 18$

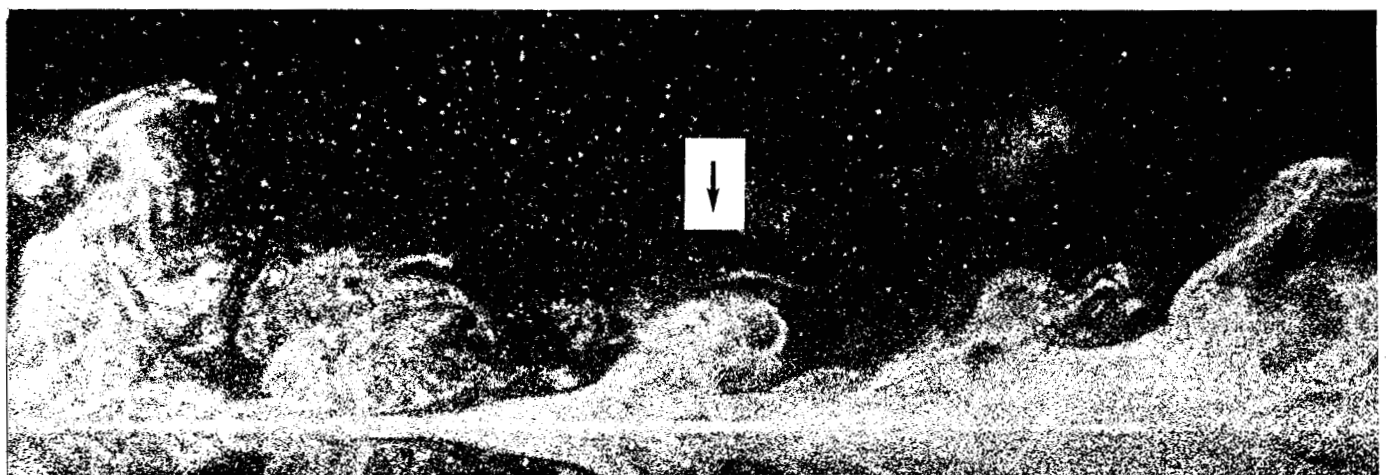
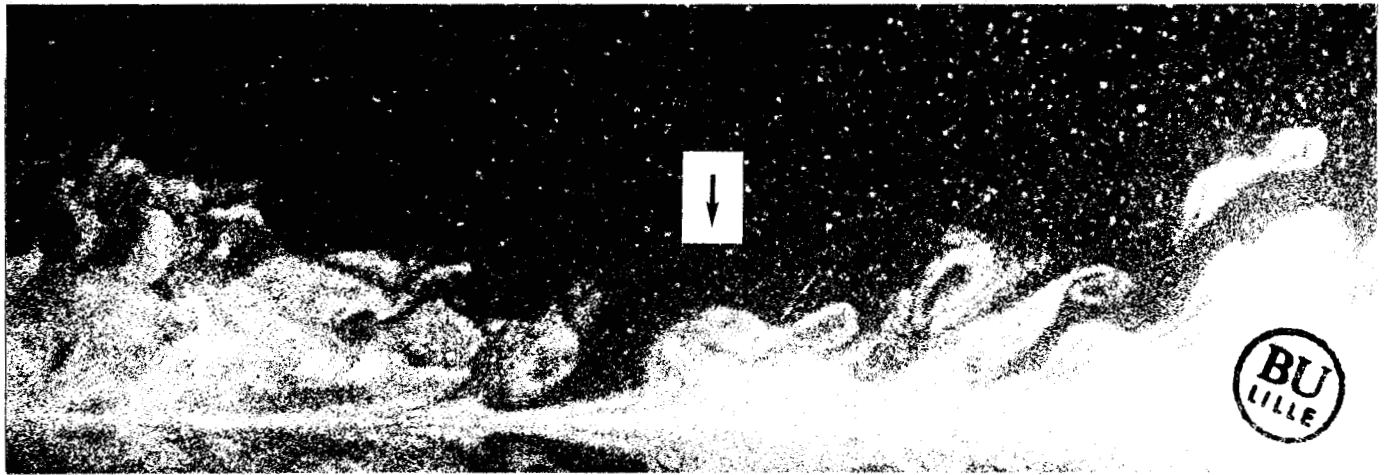
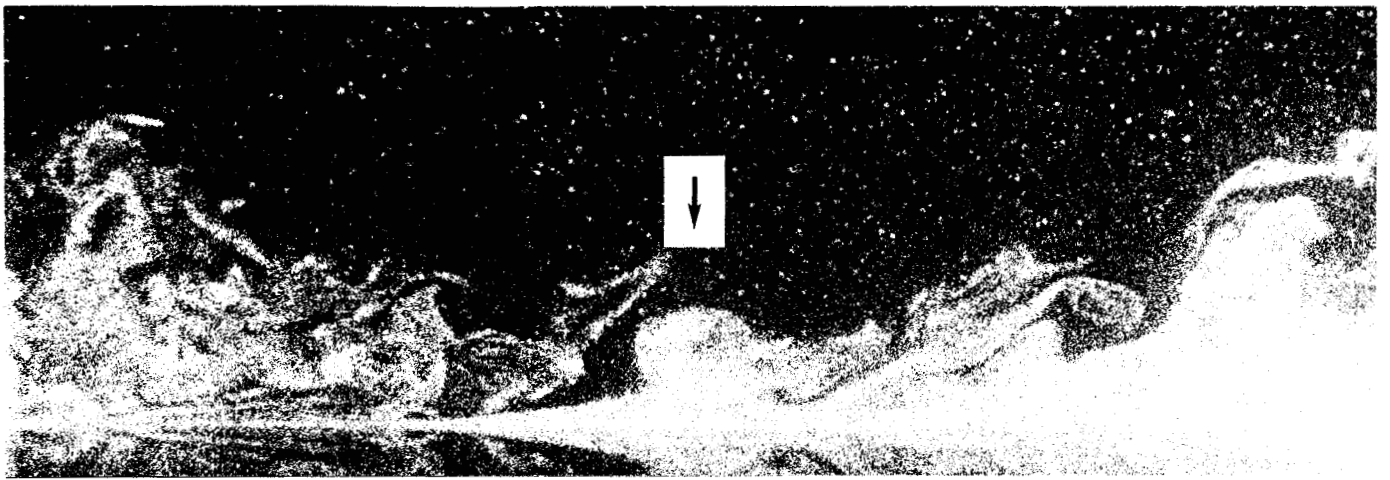


Figure 4-29 Exemple de tourbillon typique - $\Delta t^+ = 18$

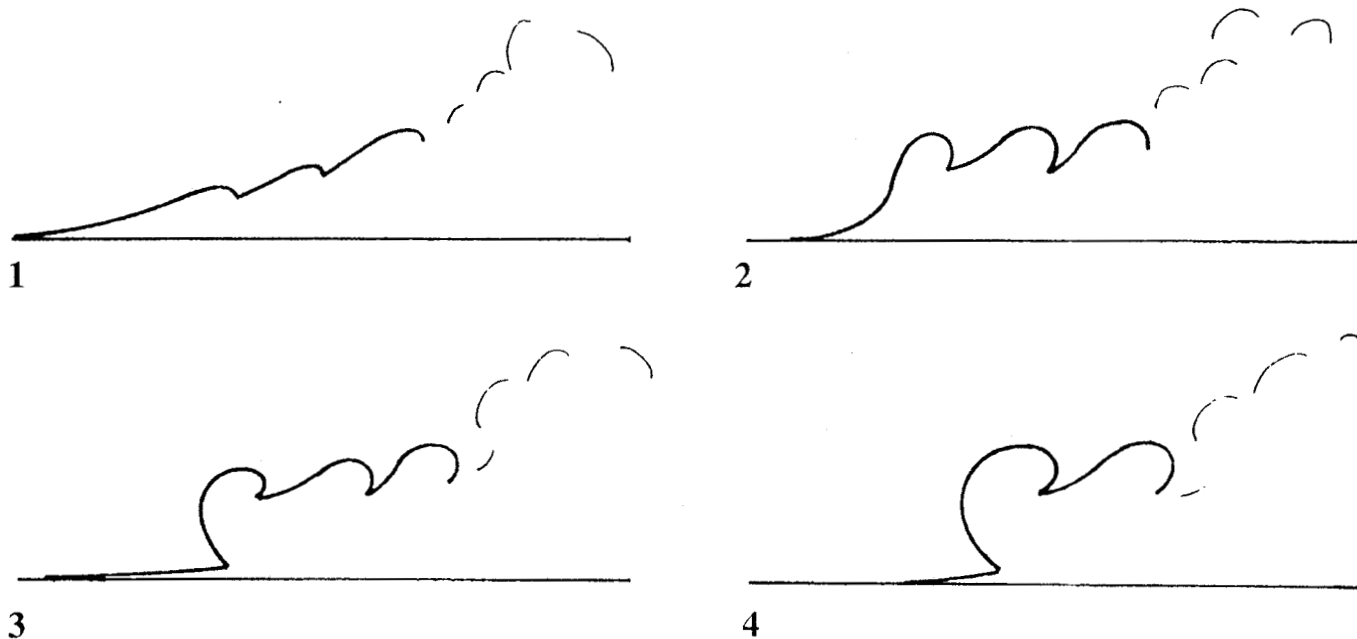


Figure 4-30 Schéma du phénomène d'instabilité

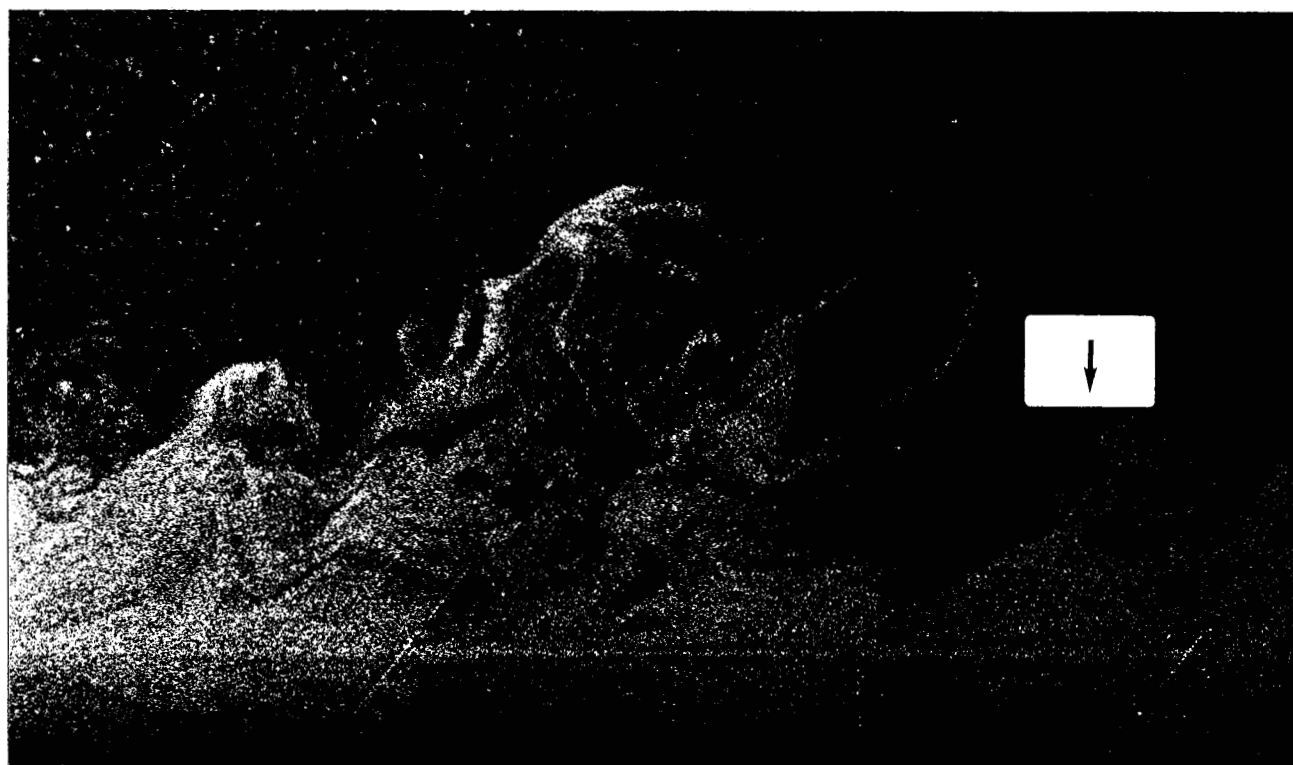


Figure 4-31 Exemple de tourbillon typique

+ simple injection
 x double injection

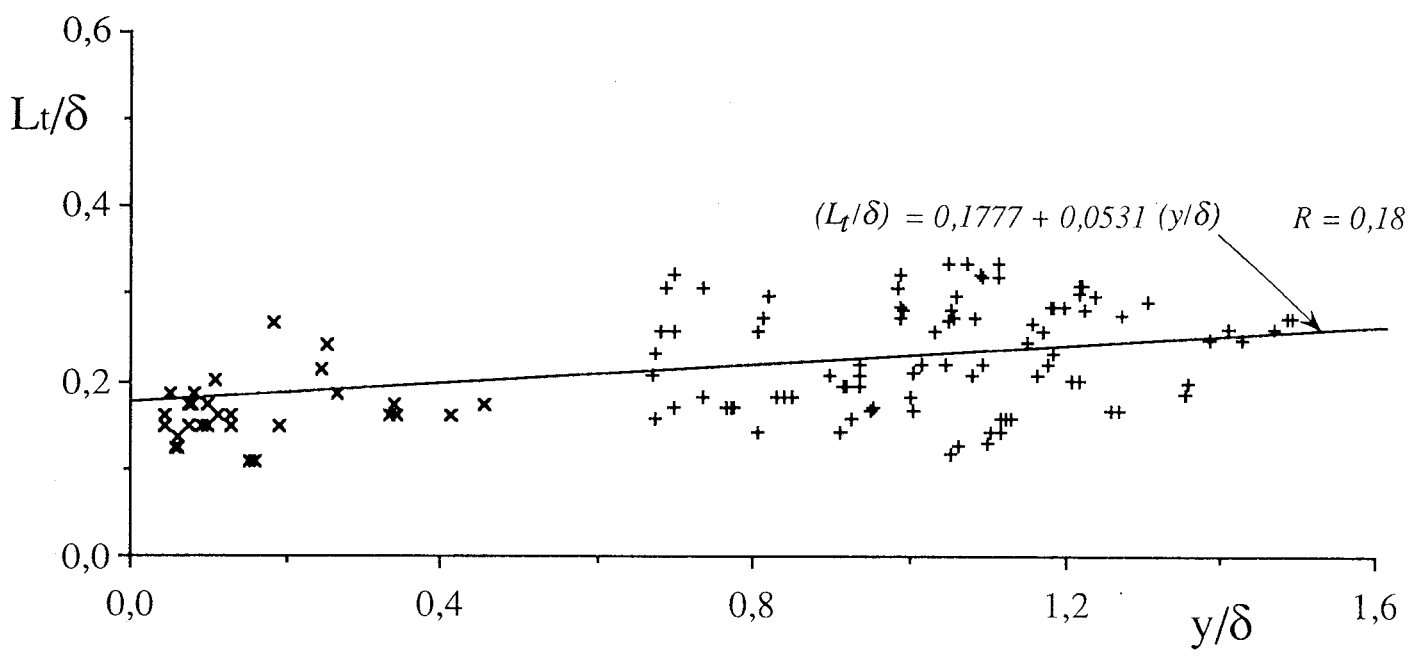
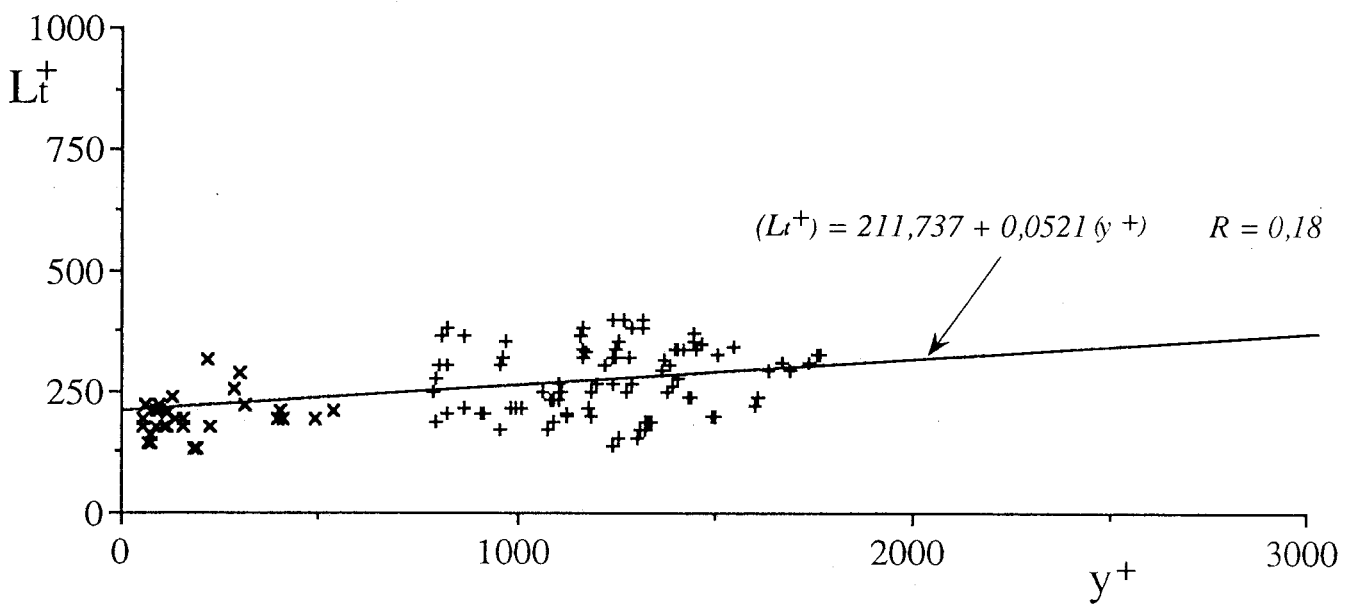


Figure 4-32 Comparaison de la dimension L_t des tourbillons typiques à l'intérieur et à l'extérieur de la couche limite
 $Re_\theta = 3515$

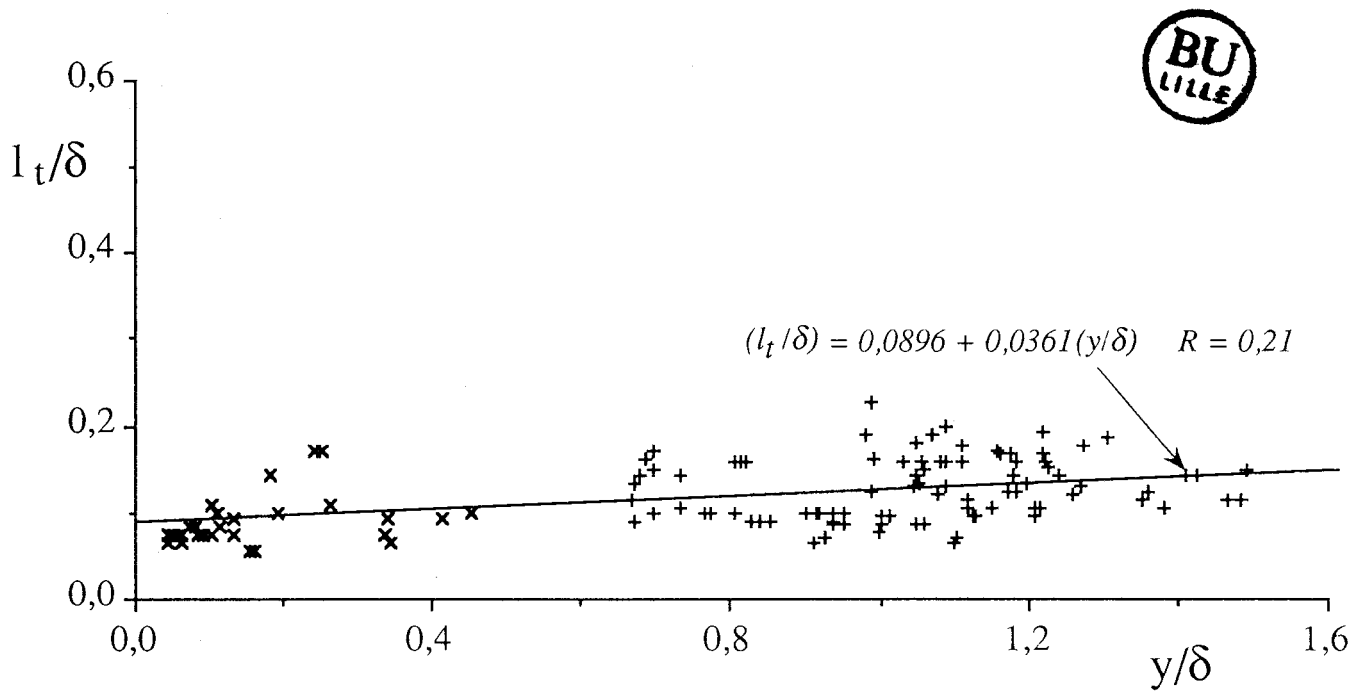
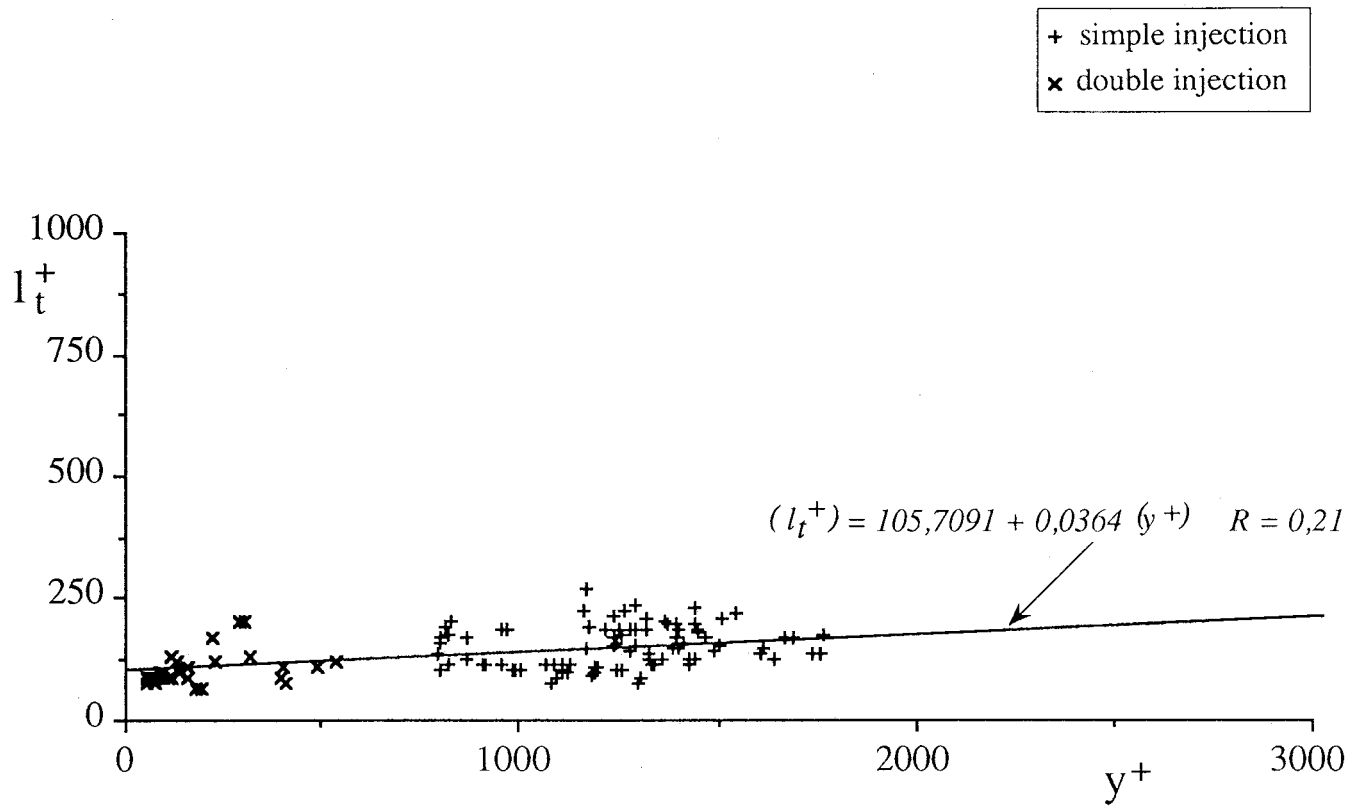


Figure 4-33 Comparaison de la dimension l_t des tourbillons typiques à l'intérieur et à l'extérieur de la couche limite
 $Re_\theta = 3515$

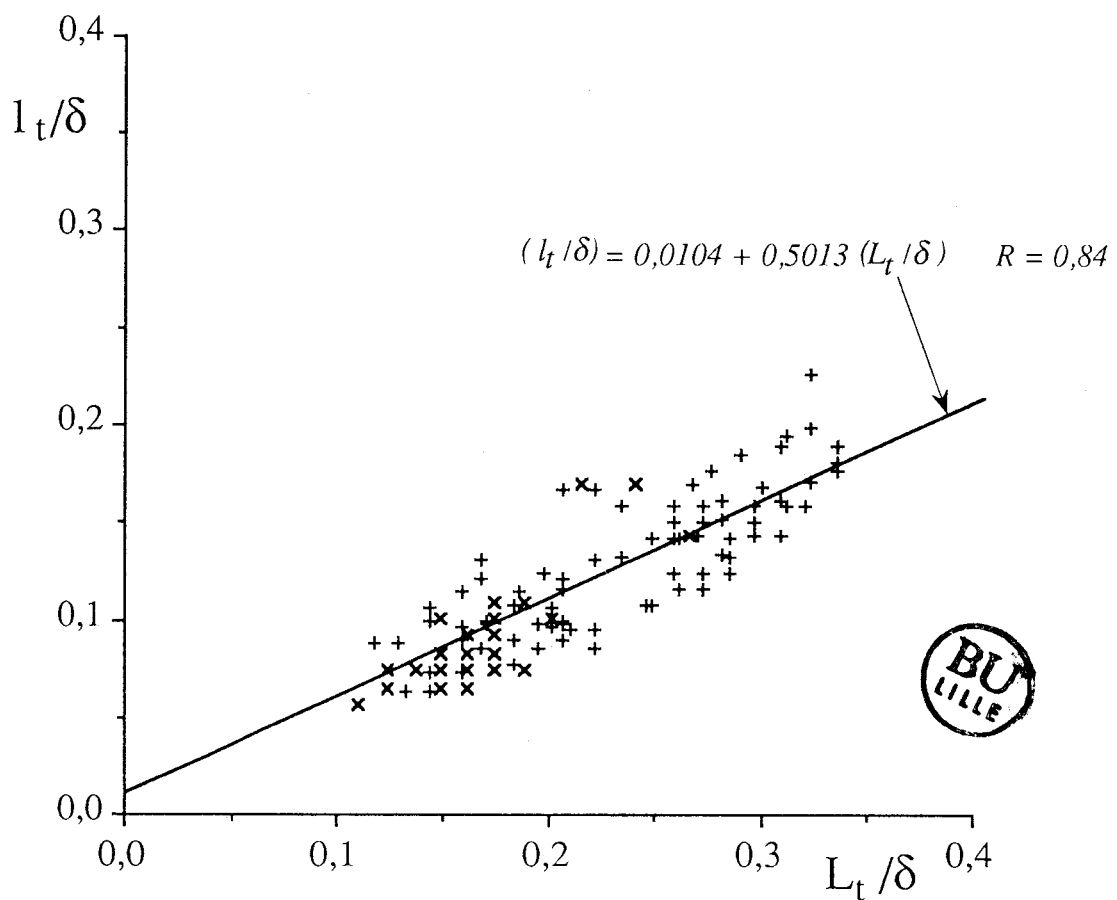
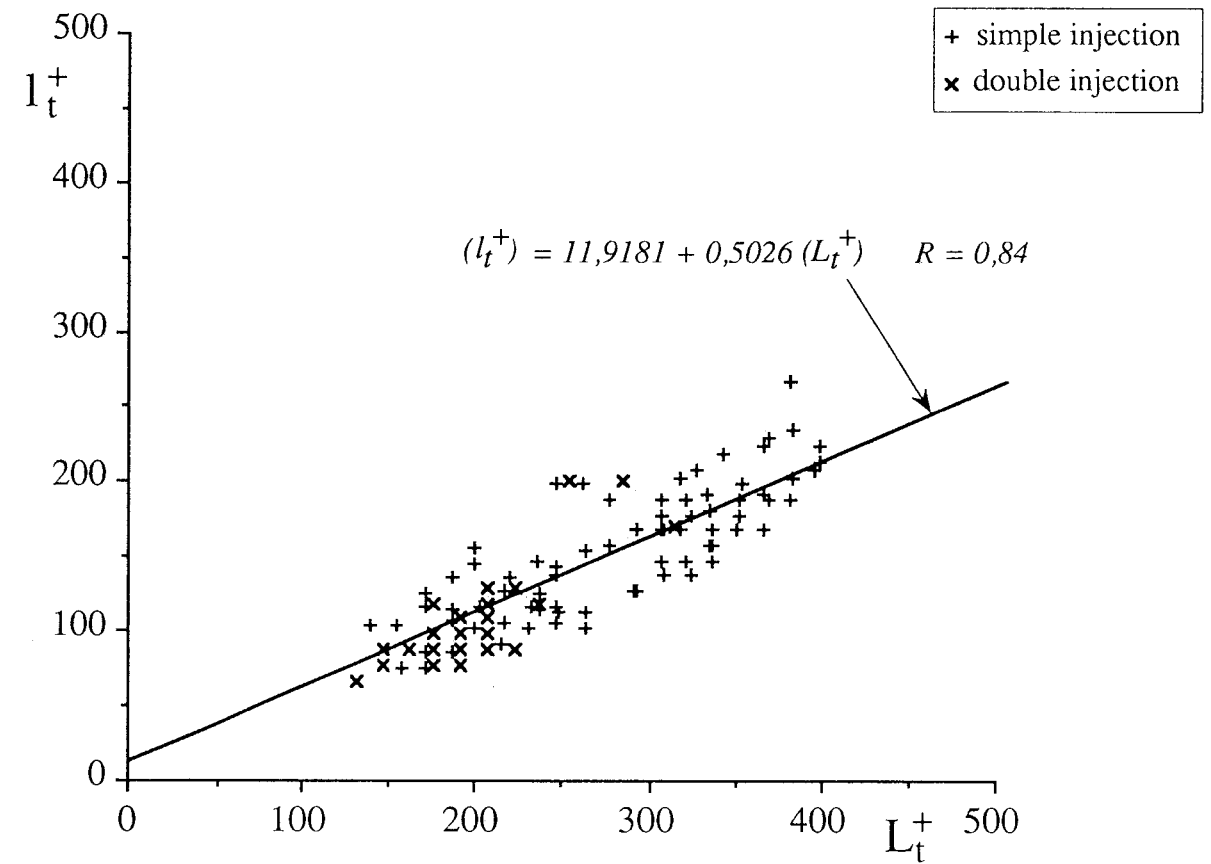


Figure 4-34 Evolutions respectives des dimensions des tourbillons typiques à l'intérieur et à l'extérieur de la couche limite
 $Re_\theta = 3515$

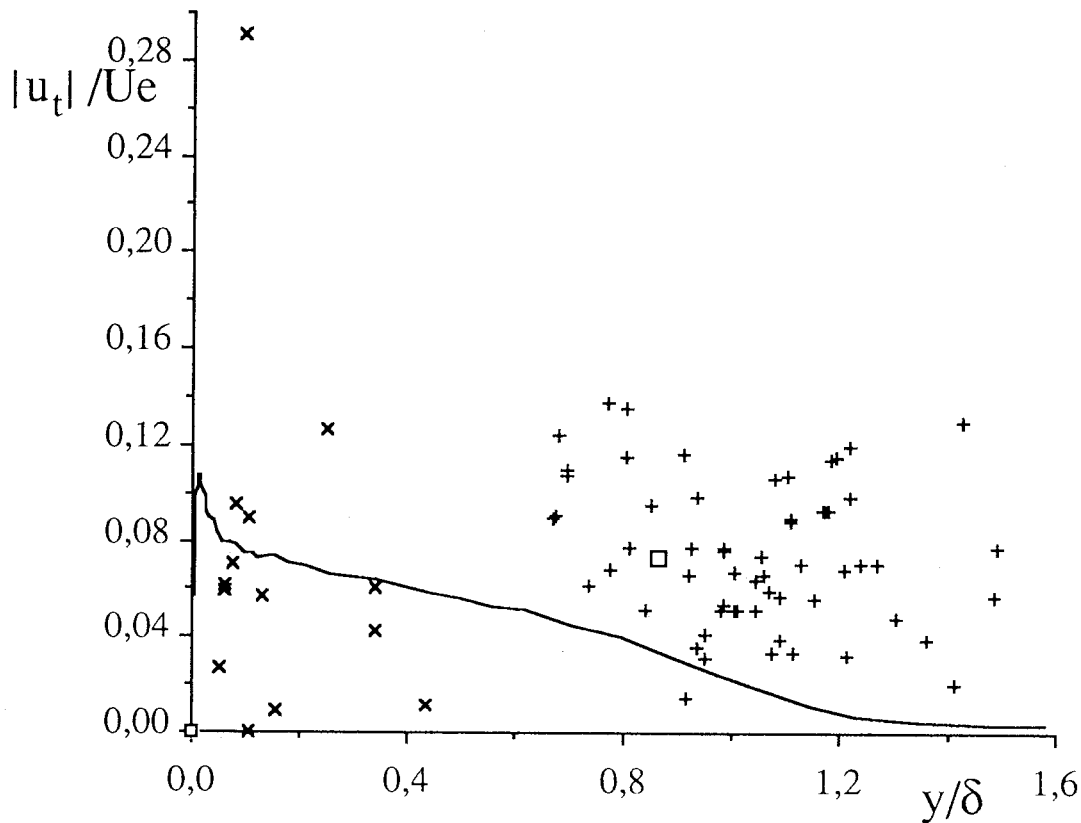
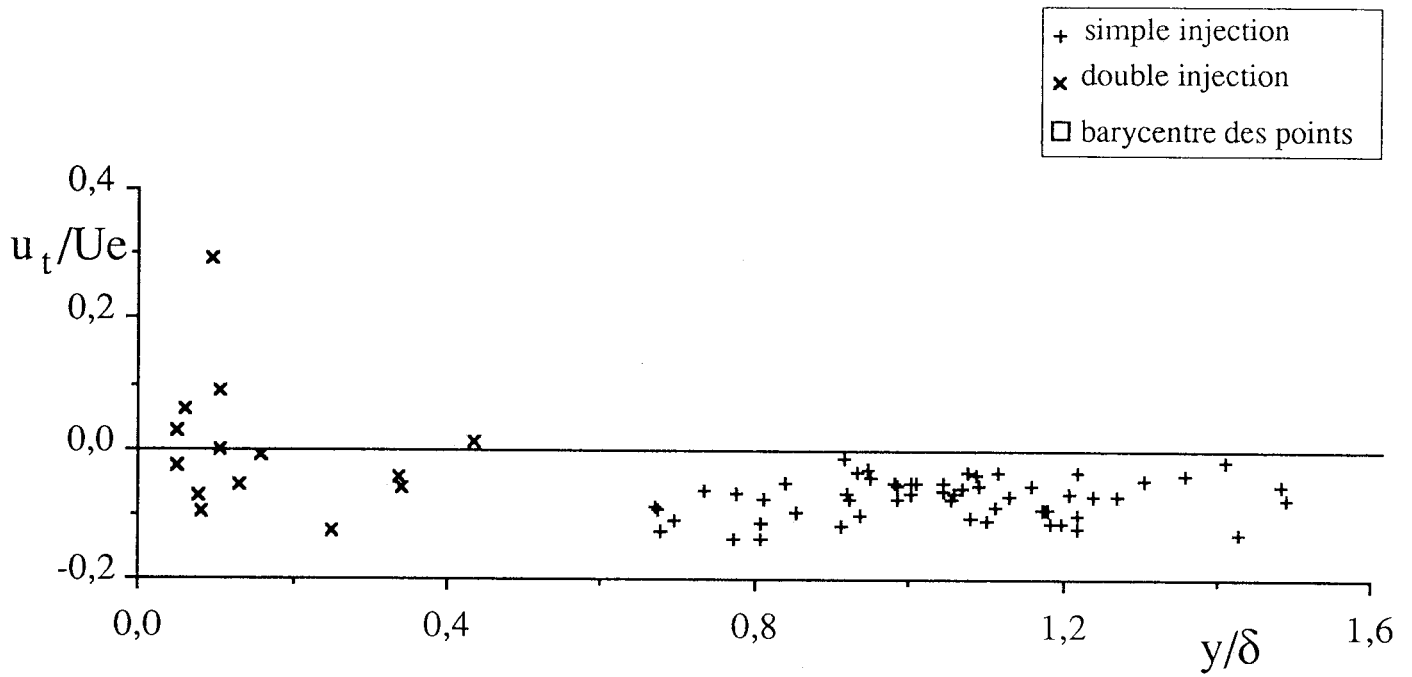


Figure 4-35 Vitesse relative longitudinale des tourbillons typiques à l'intérieur et à l'extérieur de la couche limite
 $Re_{\theta} = 3515$

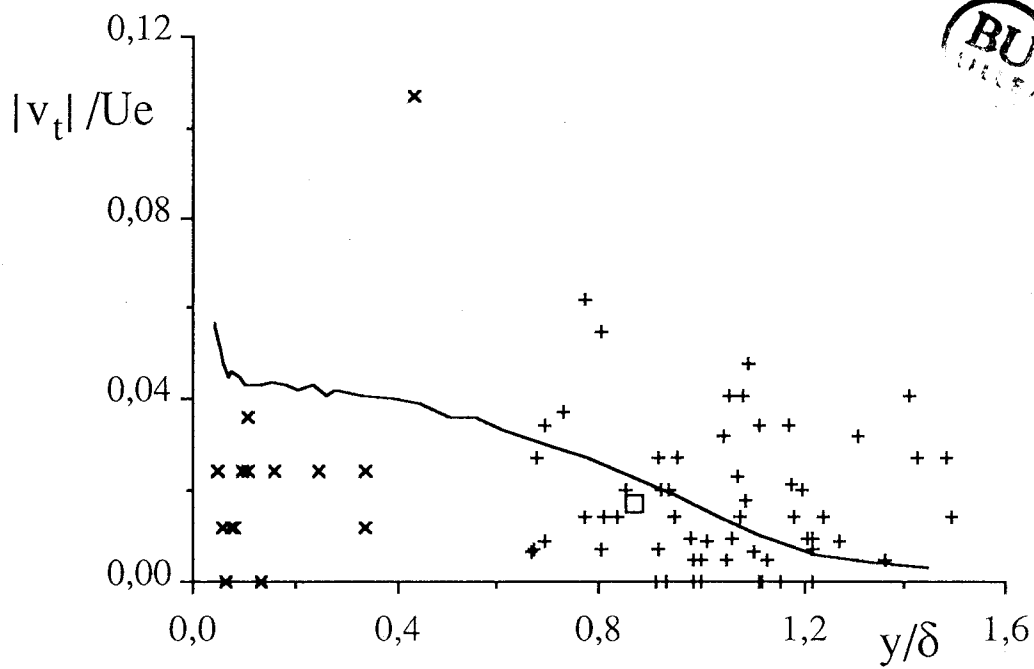
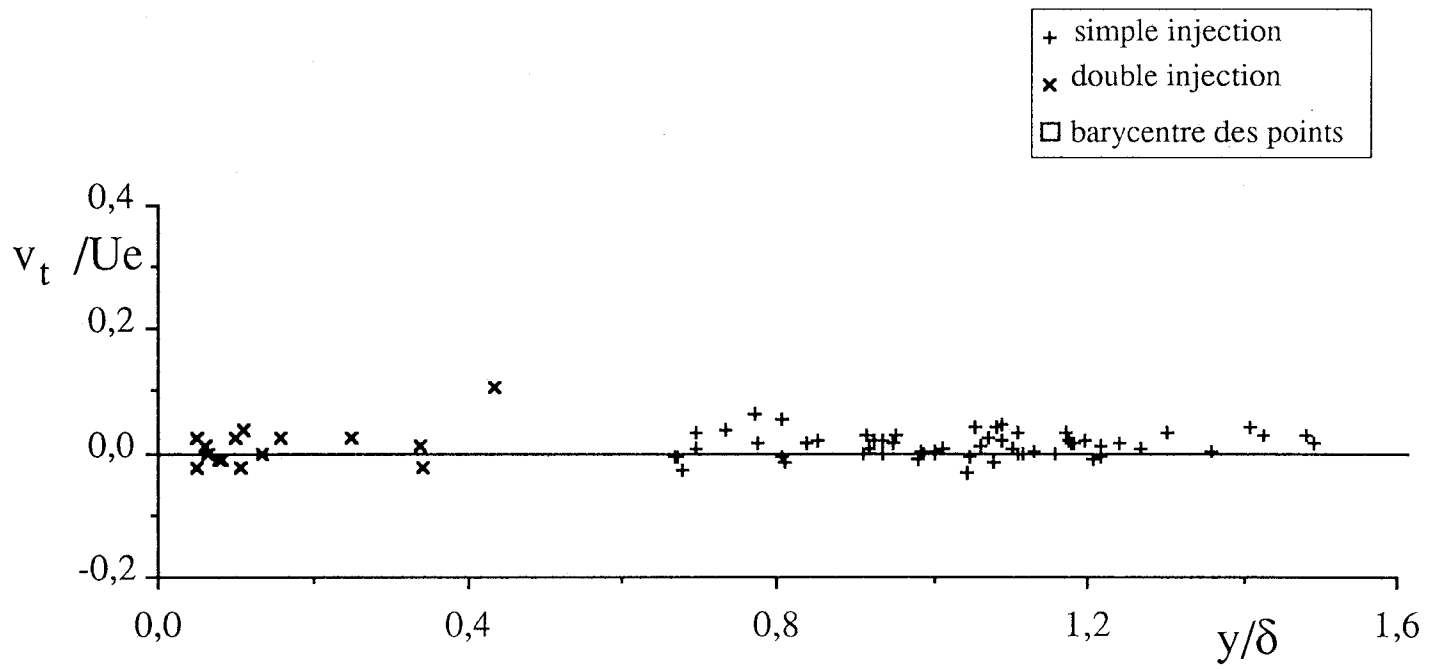


Figure 4-36 Vitesse normale des tourbillons typiques à l'intérieur et à l'extérieur de la couche limite
 $Re_0 = 3515$

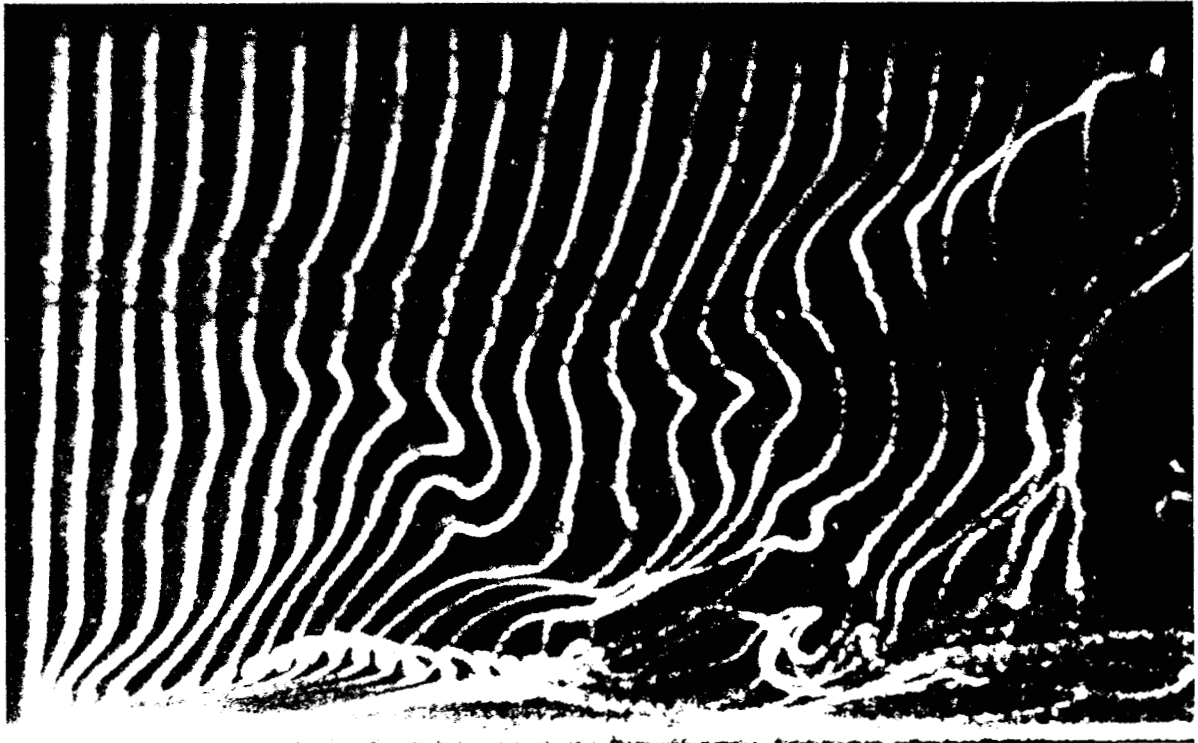


Figure 4-37a: Visualisation par bulles d'hydrogène
d'une couche limite turbulente [6]

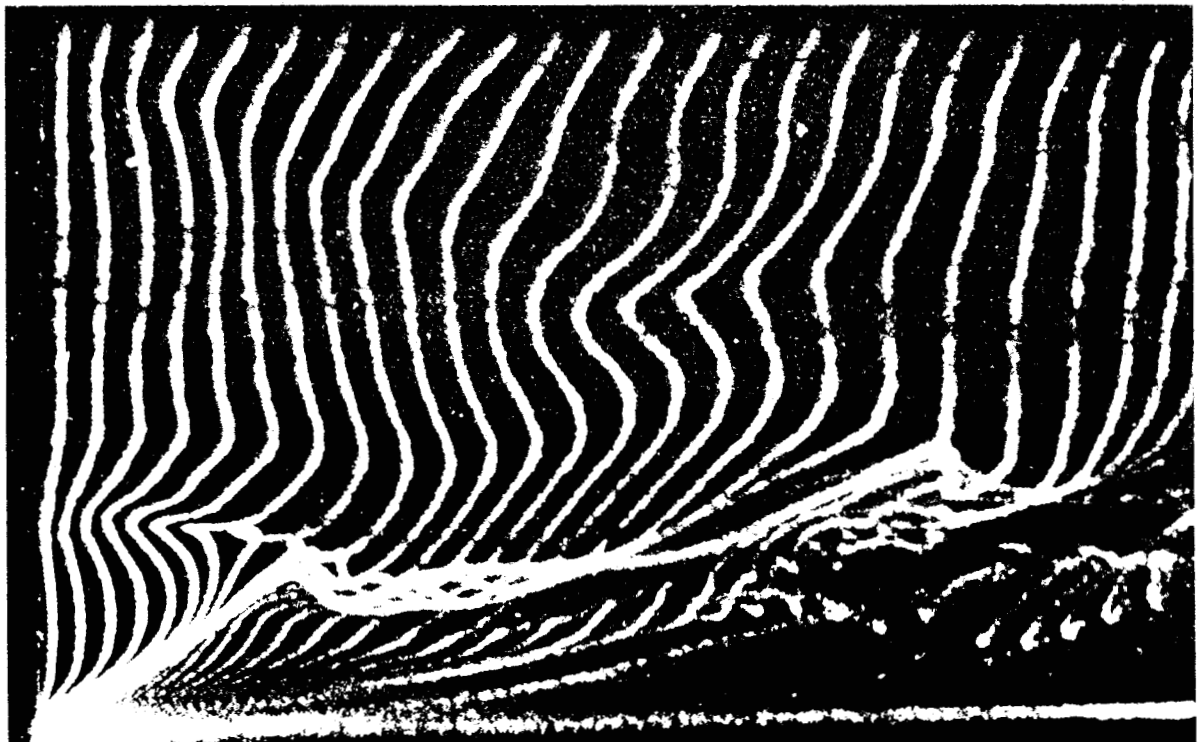


Figure 4-37b: Visualisation par bulles d'hydrogène
d'une couche limite turbulente [6]

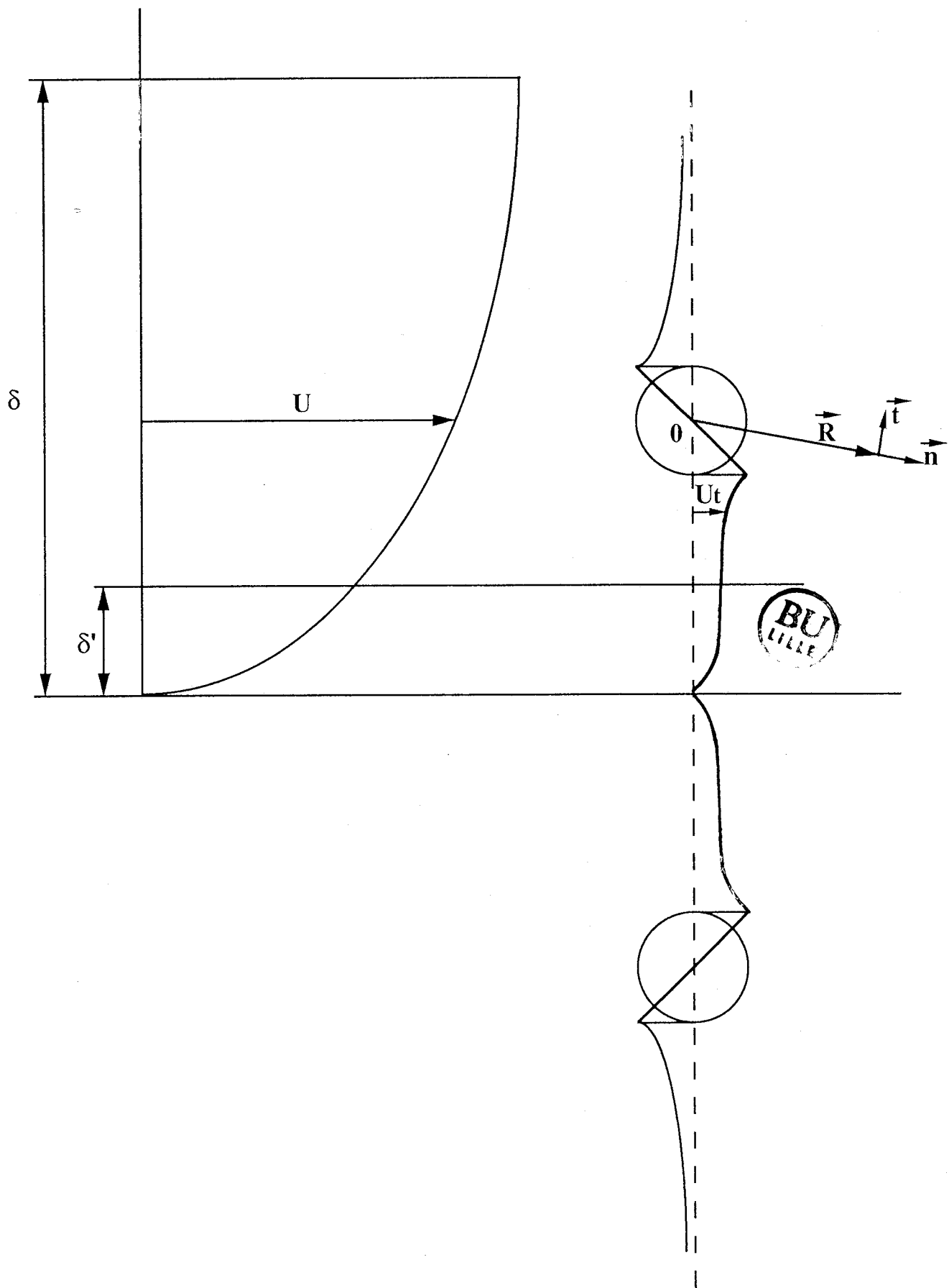


Figure 4-38 Modèle de simulation d'une structure tourbillonnaire dans une couche limite turbulente

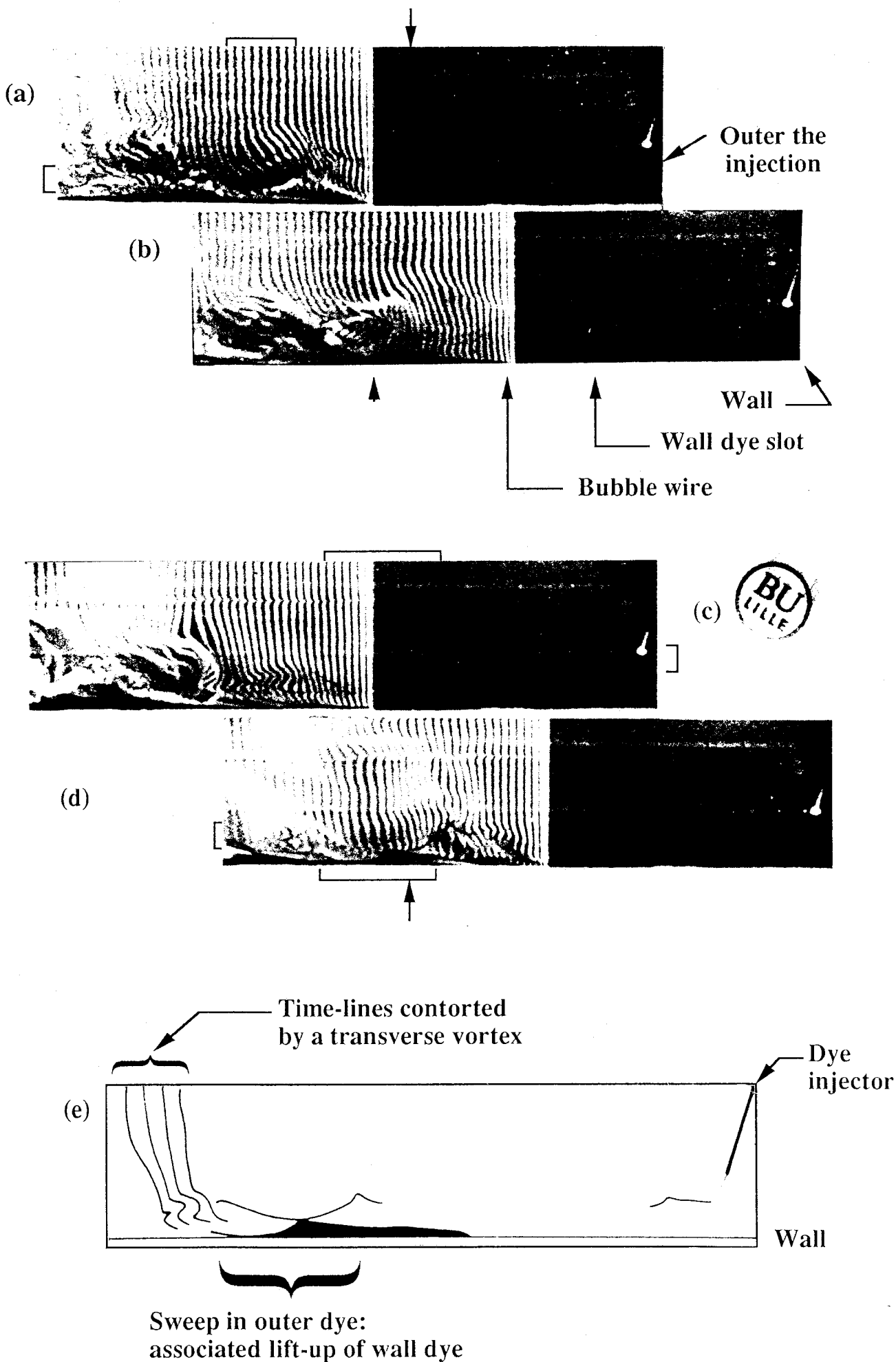
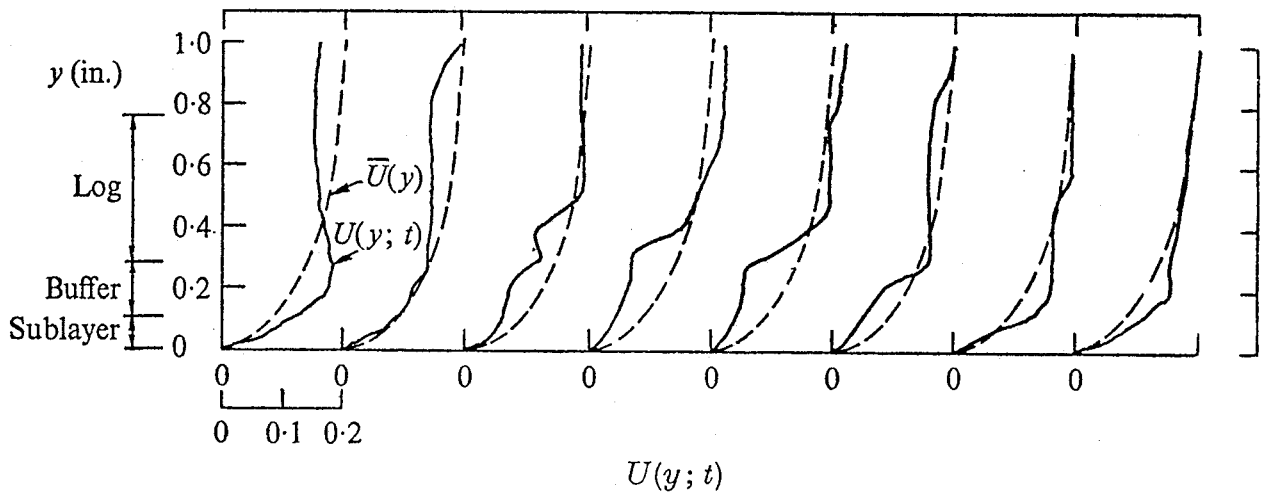
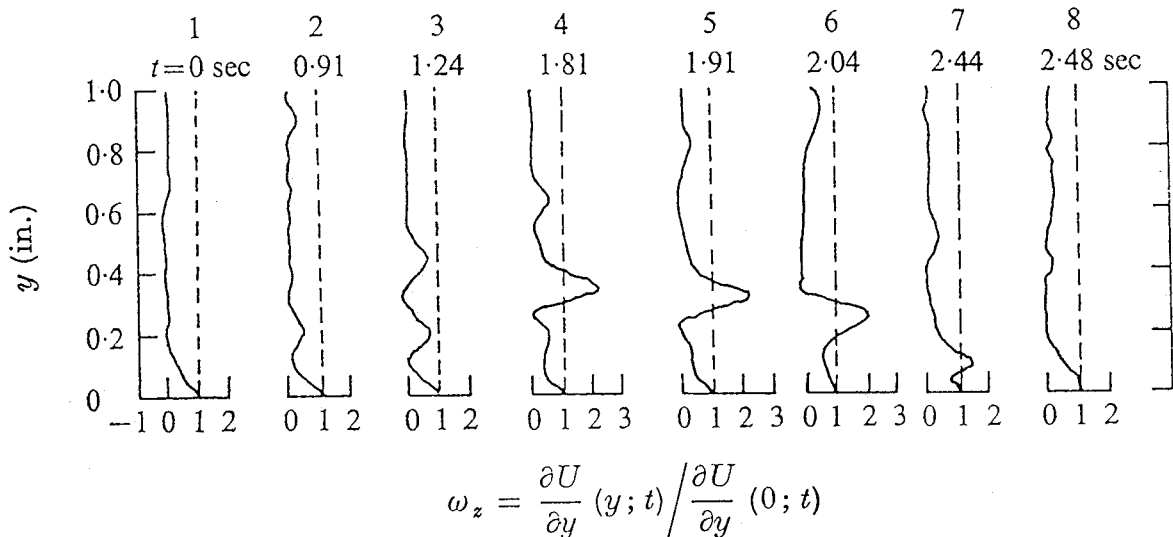


Figure 4-39: Visualisations simultanées par bulles d'hydrogène et injection de colorant à la paroi [13]



Comparison of instantaneous velocity profiles, $U(y; t)$, with the mean profile $\bar{U}(y)$ over a typical bursting cycle.



Instantaneous vorticity profiles, $\omega_z(y; t)$, normalized on wall value, $\partial U / \partial y (0; t)$, over a typical bursting cycle.

Figure 4-40: Profil de vitesse et de vorticit  instantan es [6]

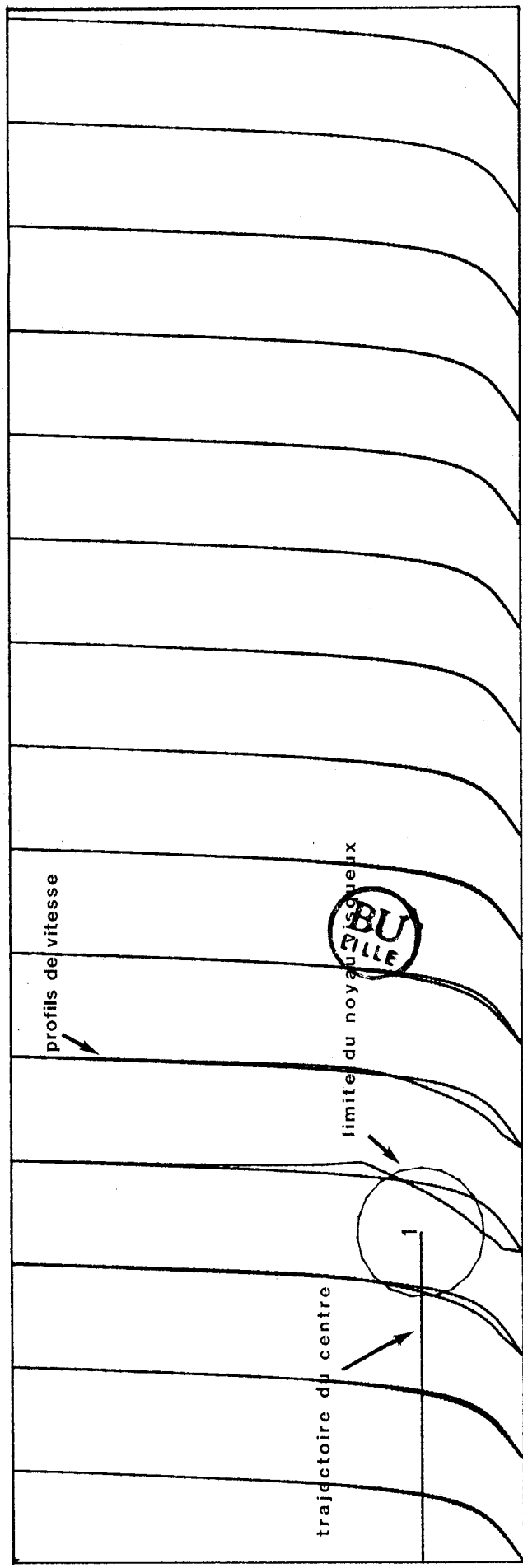
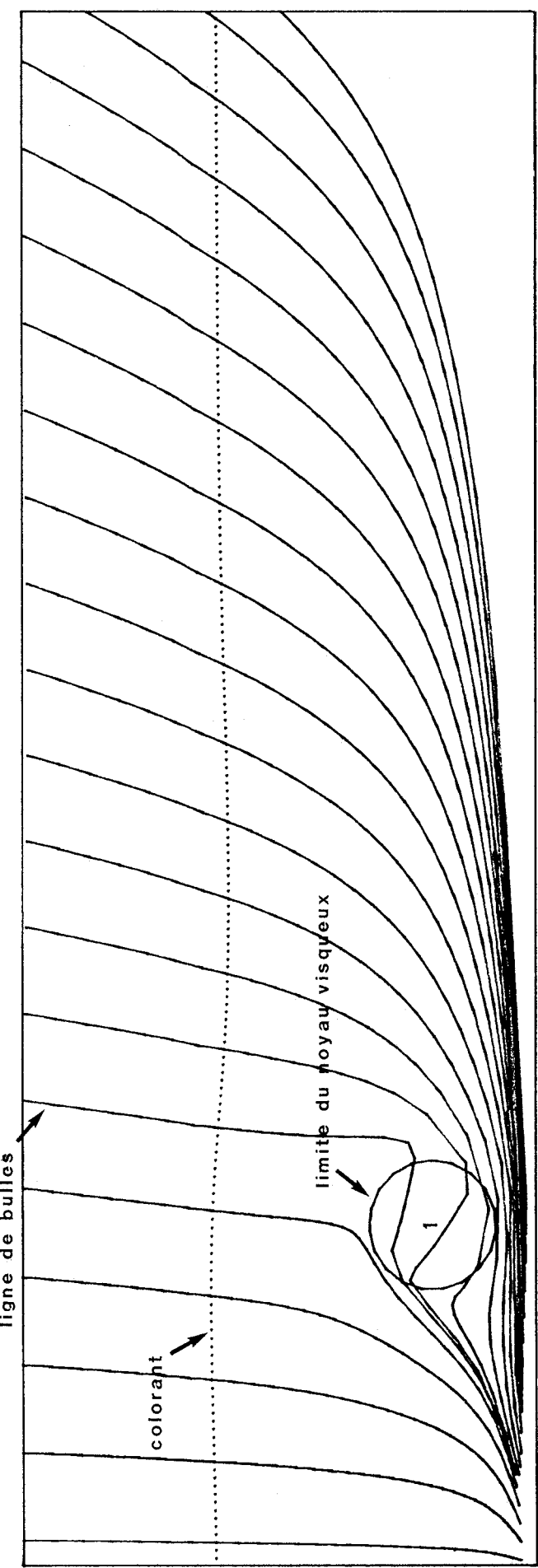


Figure 4-41: Simulation: (1) tourbillon co-rotatif

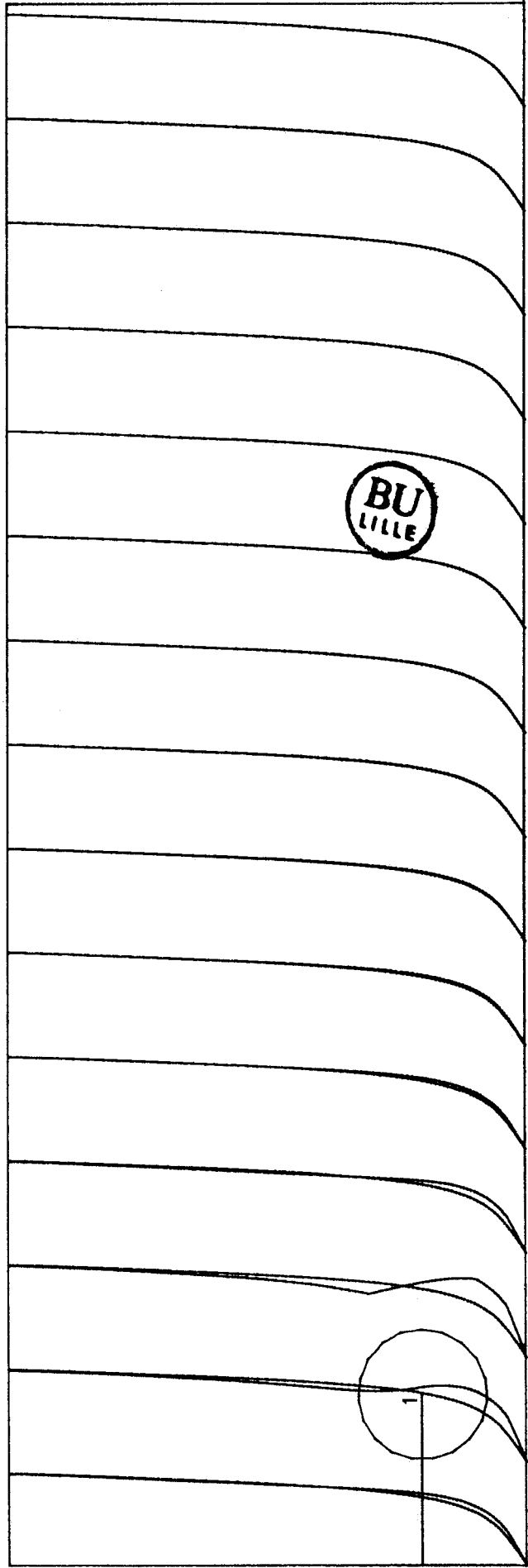
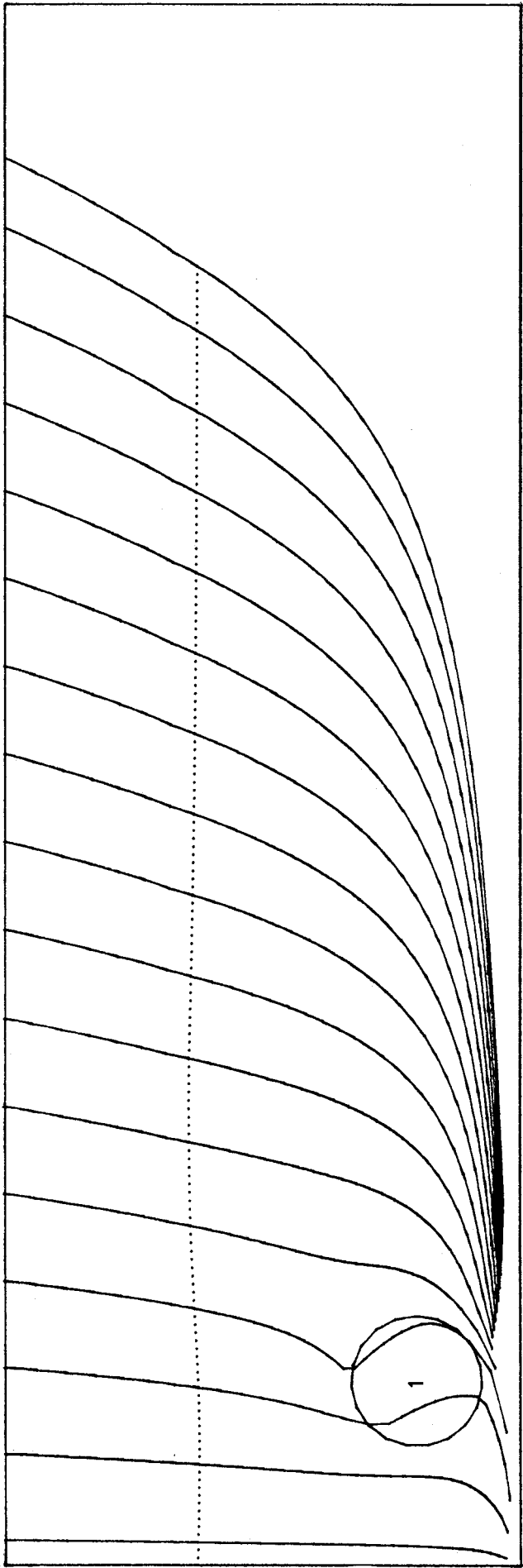


Figure 4-42: Simulation: (1) tourbillon contra-rotatif

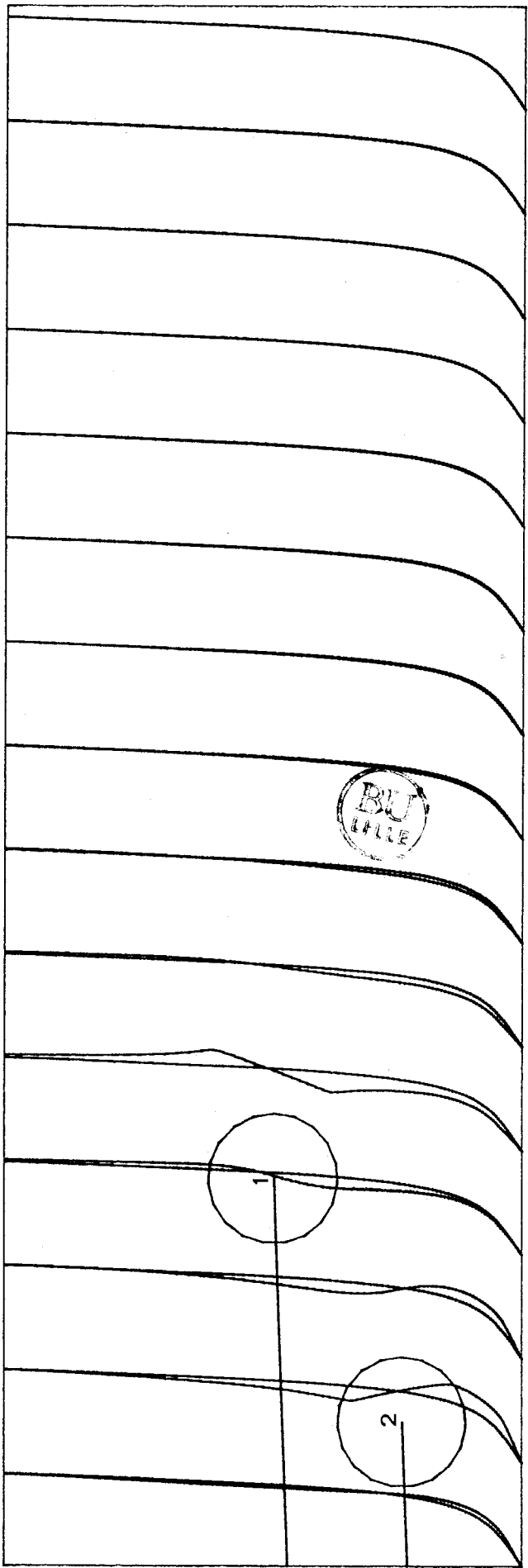
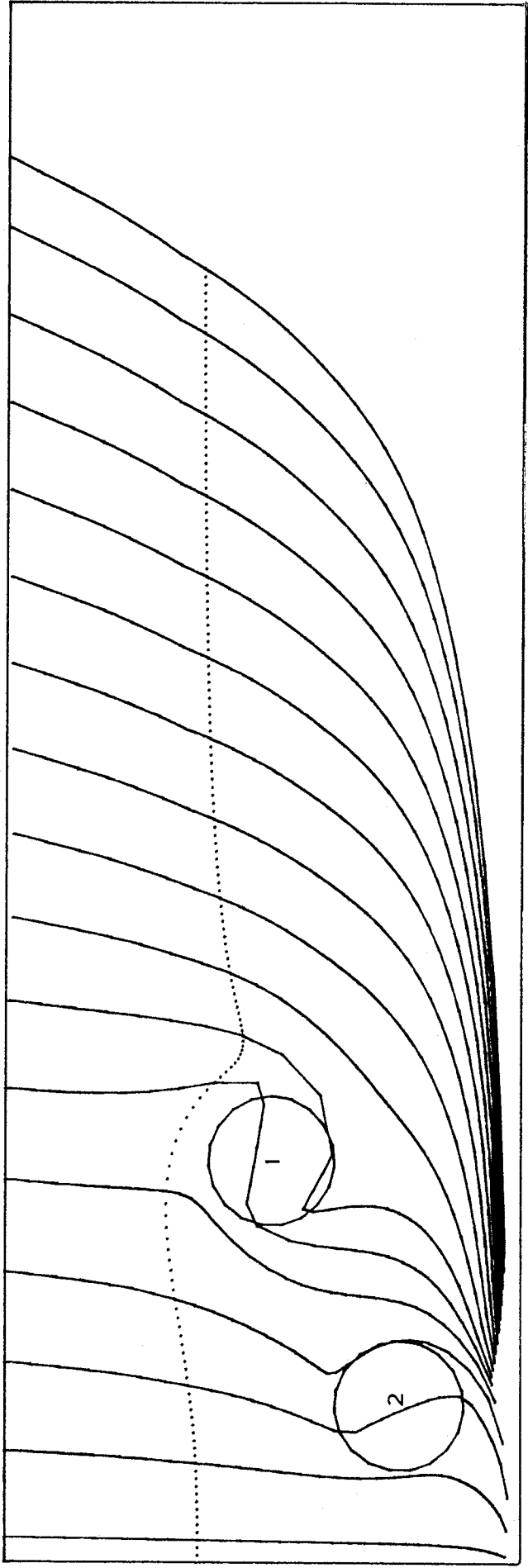


Figure 4-43: Simulation: (1) tourbillon co-rotatif
(2) tourbillon contra-rotatif

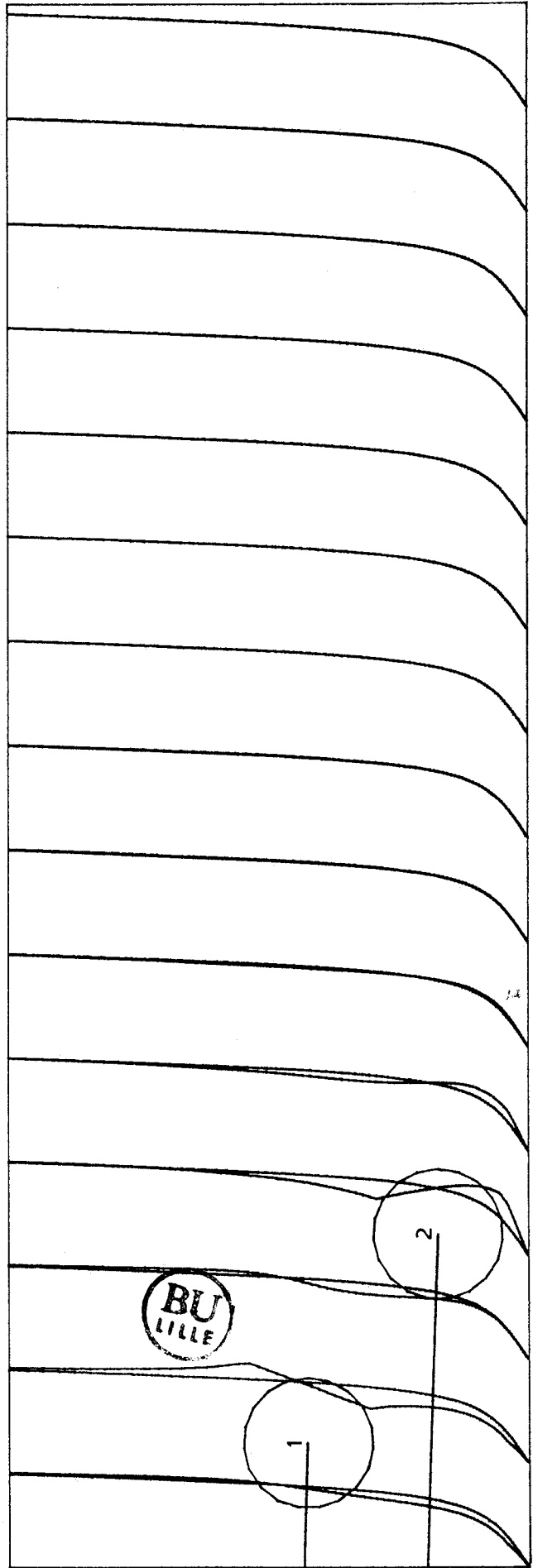
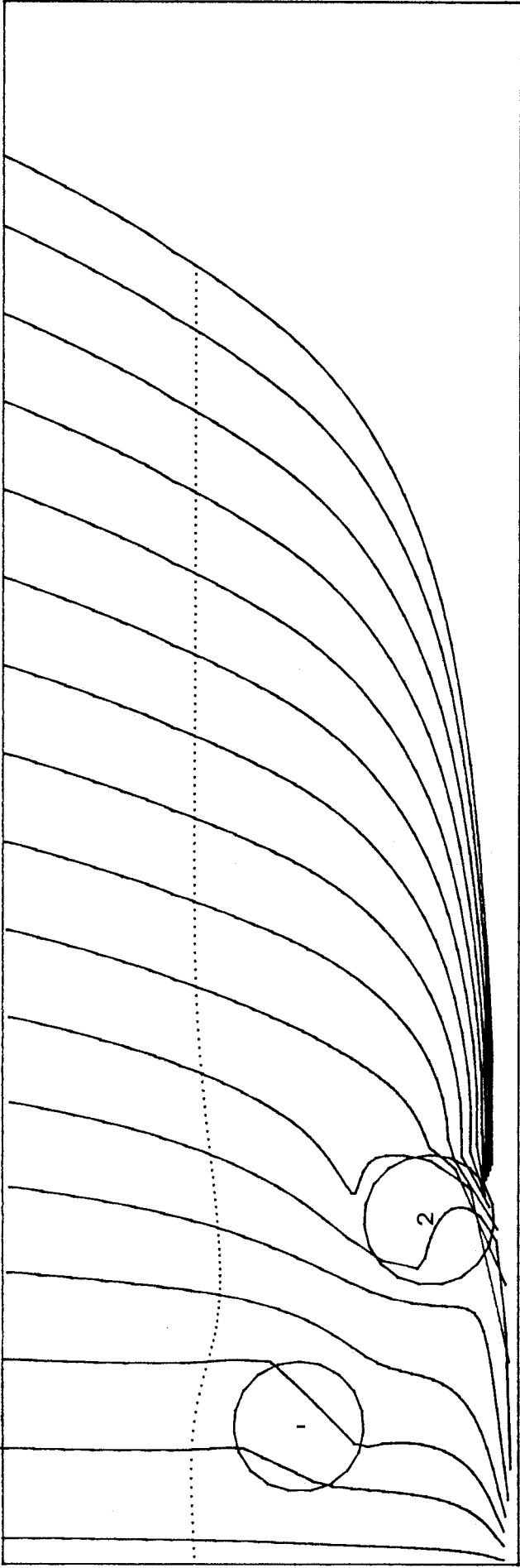


Figure 4-44: Simulation: (1) tourbillon co-rotatif
(2) tourbillon contra-rotatif

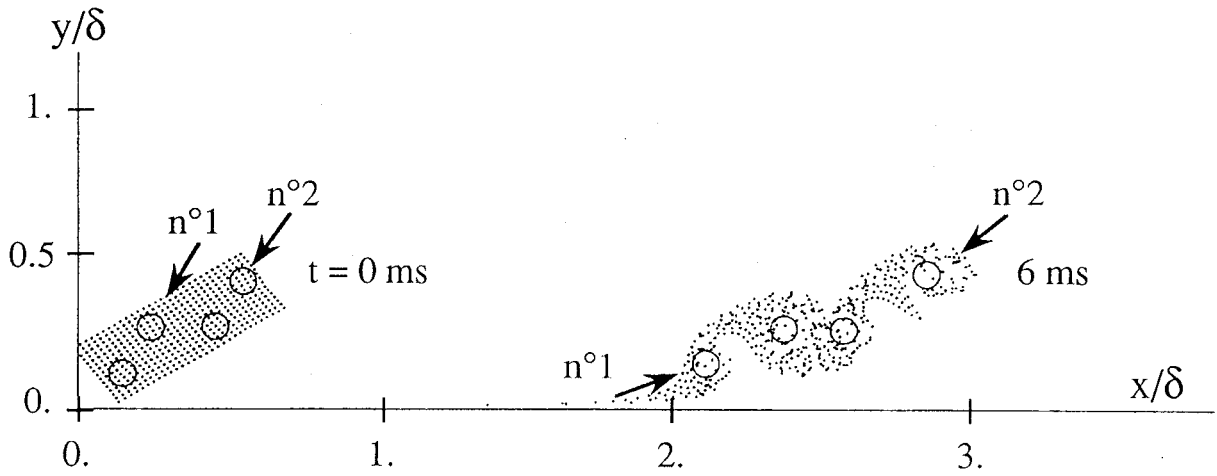
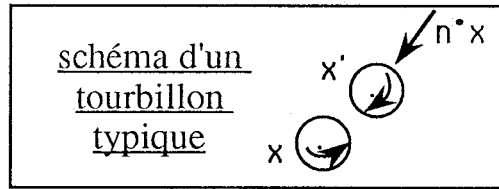


Figure 4-45-a

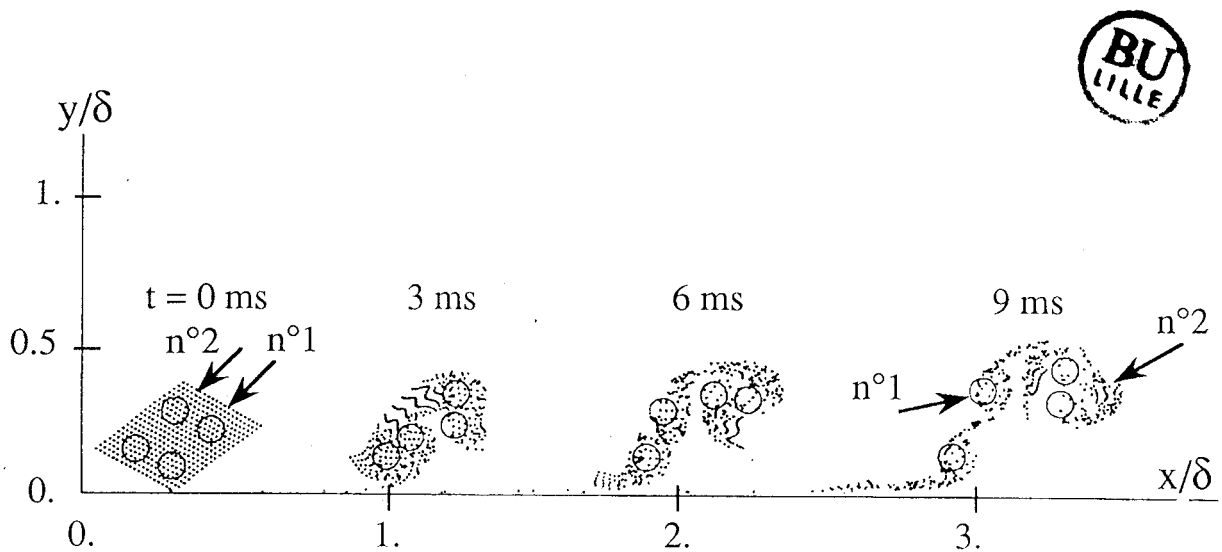


Figure 4-45-b

Figure 4-45 Simulation de l'interaction de deux tourbillons typiques

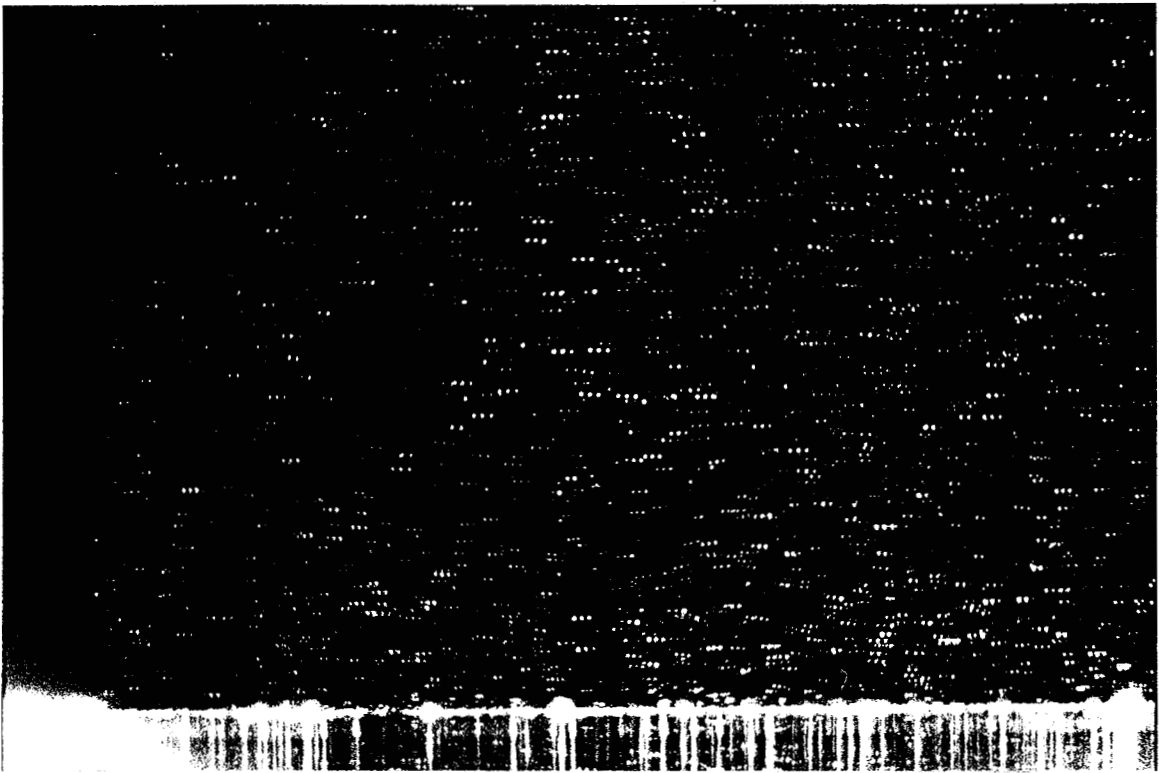


Figure 4-46 a: Exemple de cliché de V.I.P.

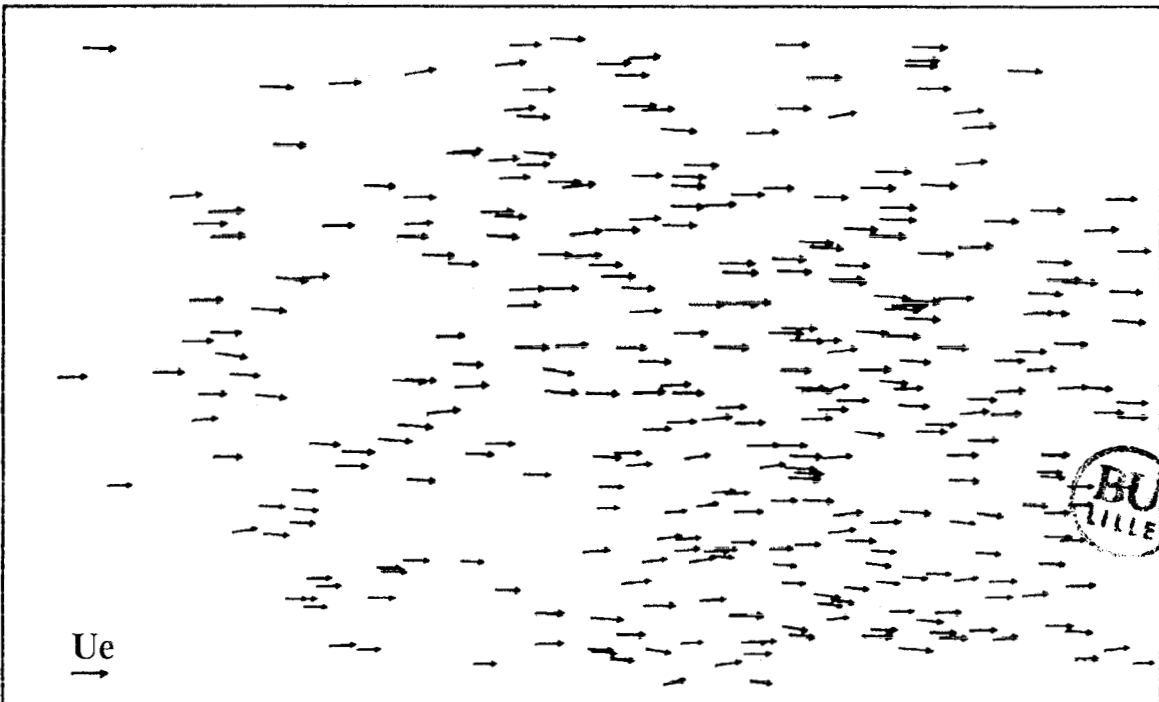


Figure 4-46 b: Exemple de carte de vitesse - $U_e = 12,6$ m/s

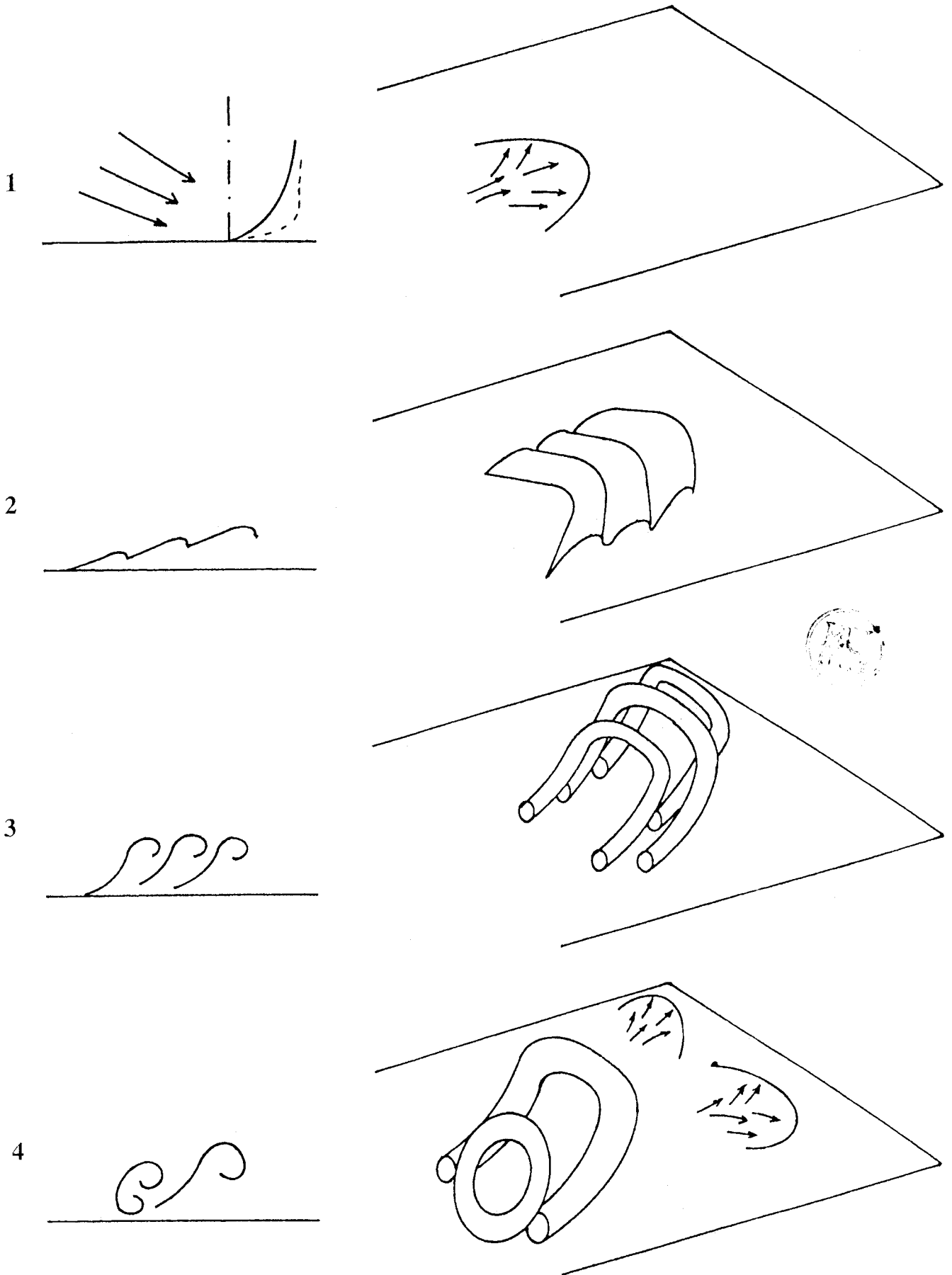


Figure 4-47 Schéma de principe du modèle de mécanisme de production

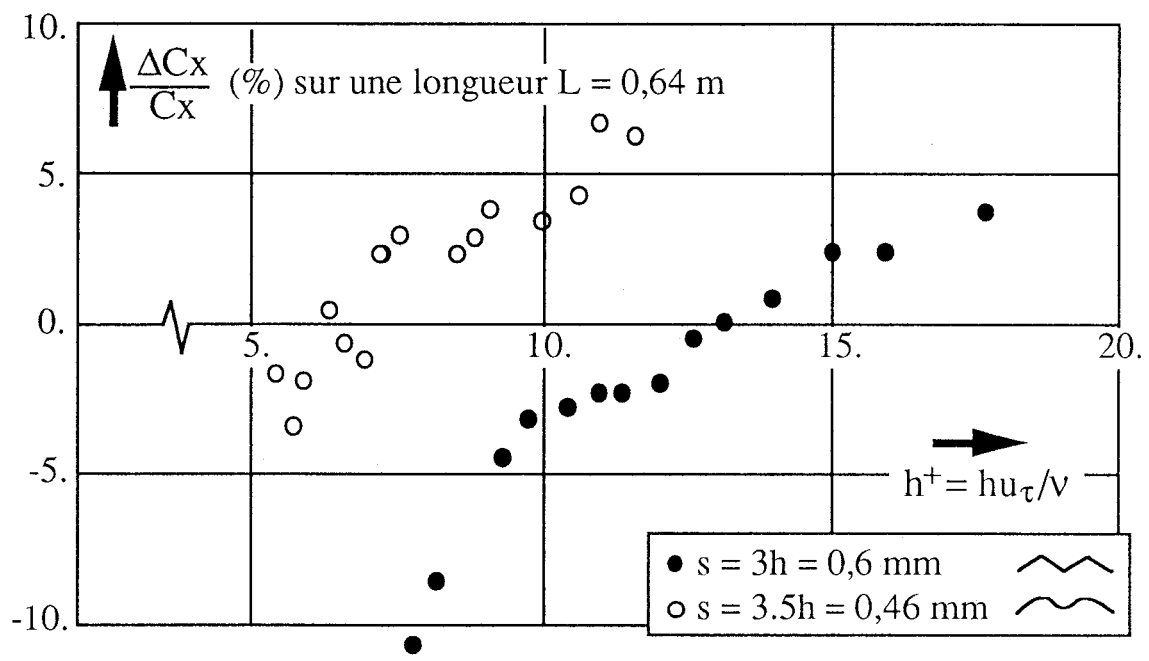
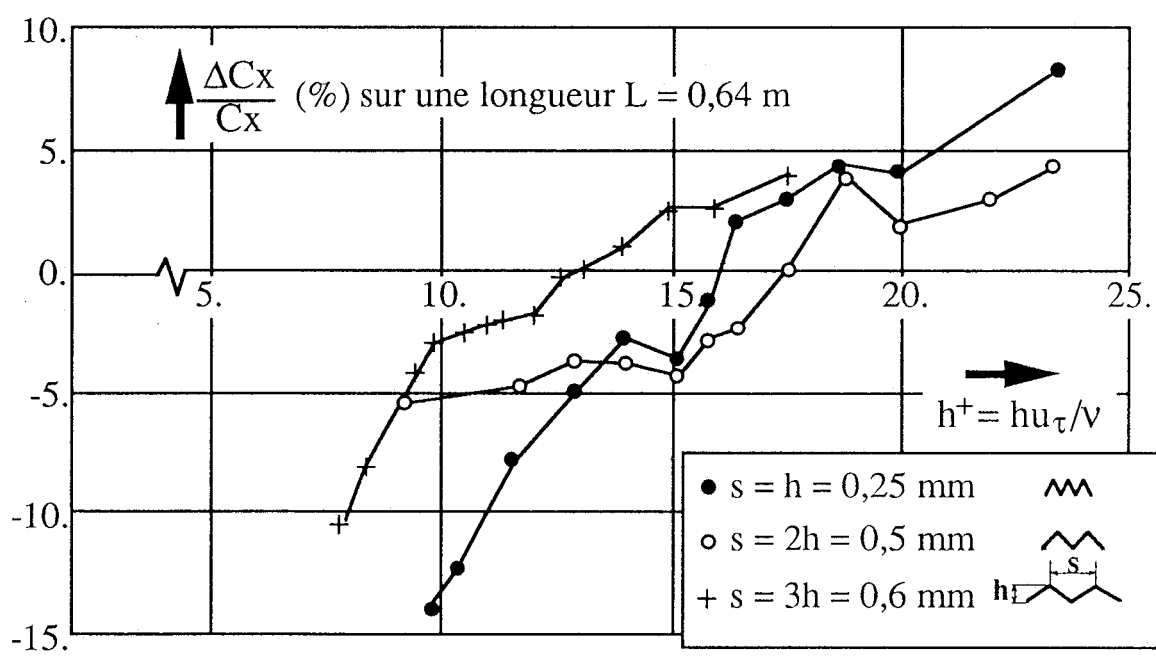


Figure 5-1 Variations du coefficient de traînée en fonction de la géométrie des riblets [56]

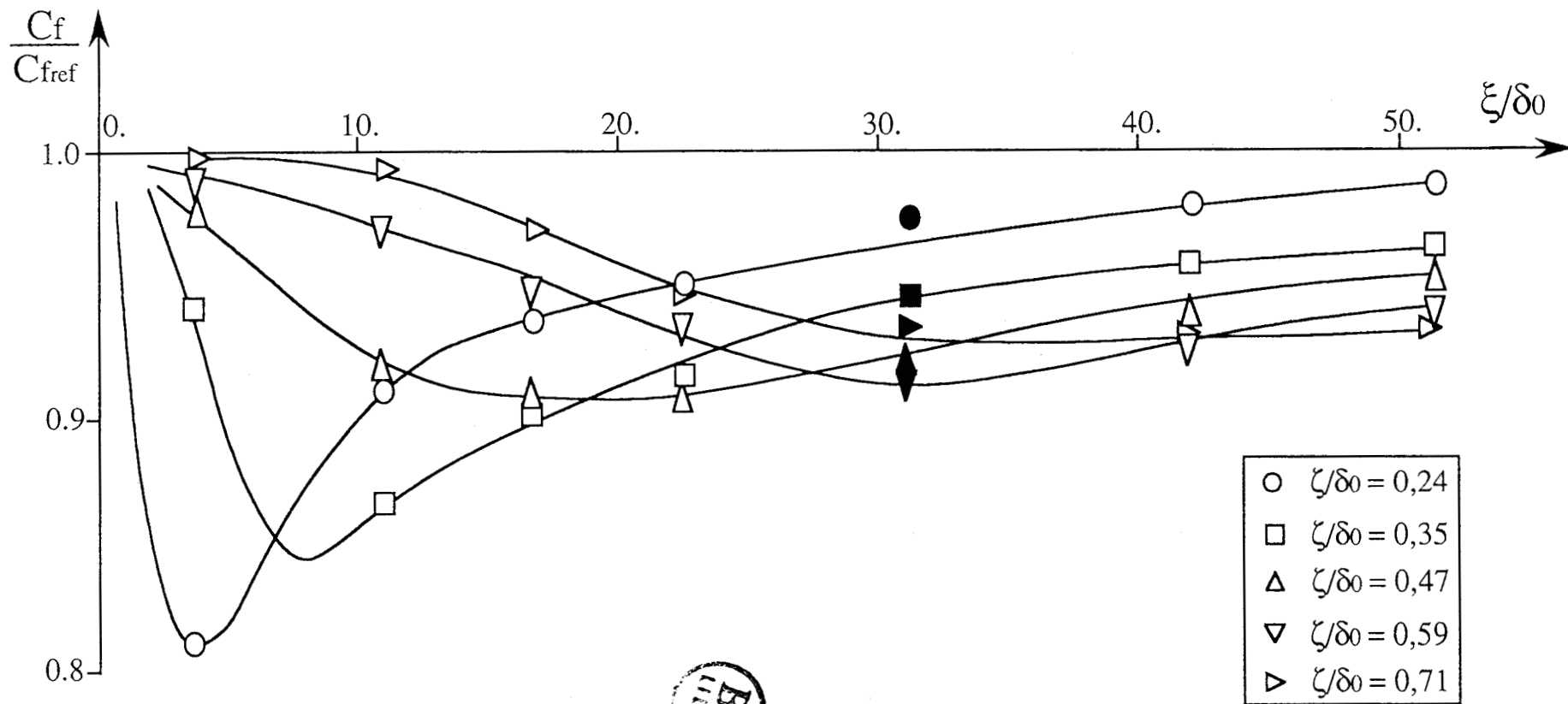


Figure 5-2 Evolution longitudinale du coefficient de frottement en fonction de la hauteur du manipulateur dans la couche limite [56]

(symboles pleins = balance de traînée, symboles vides = sonde de frottement)

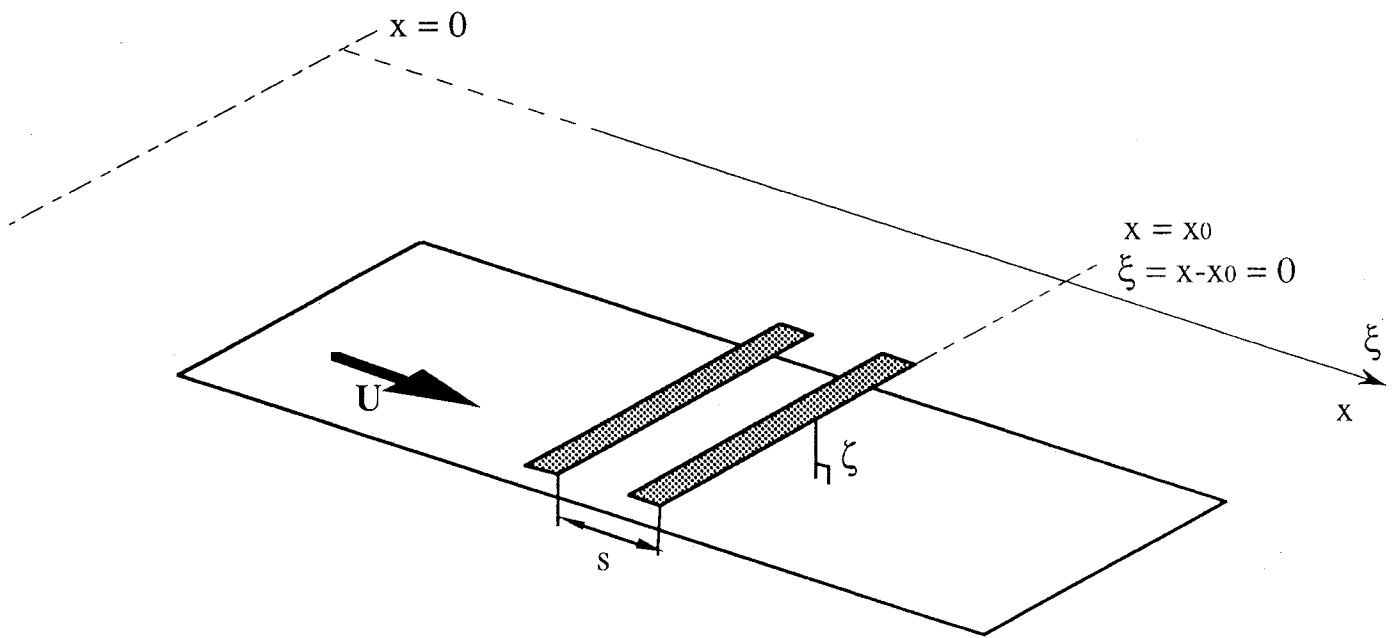


Figure 5-3 Manipulateur en tandem

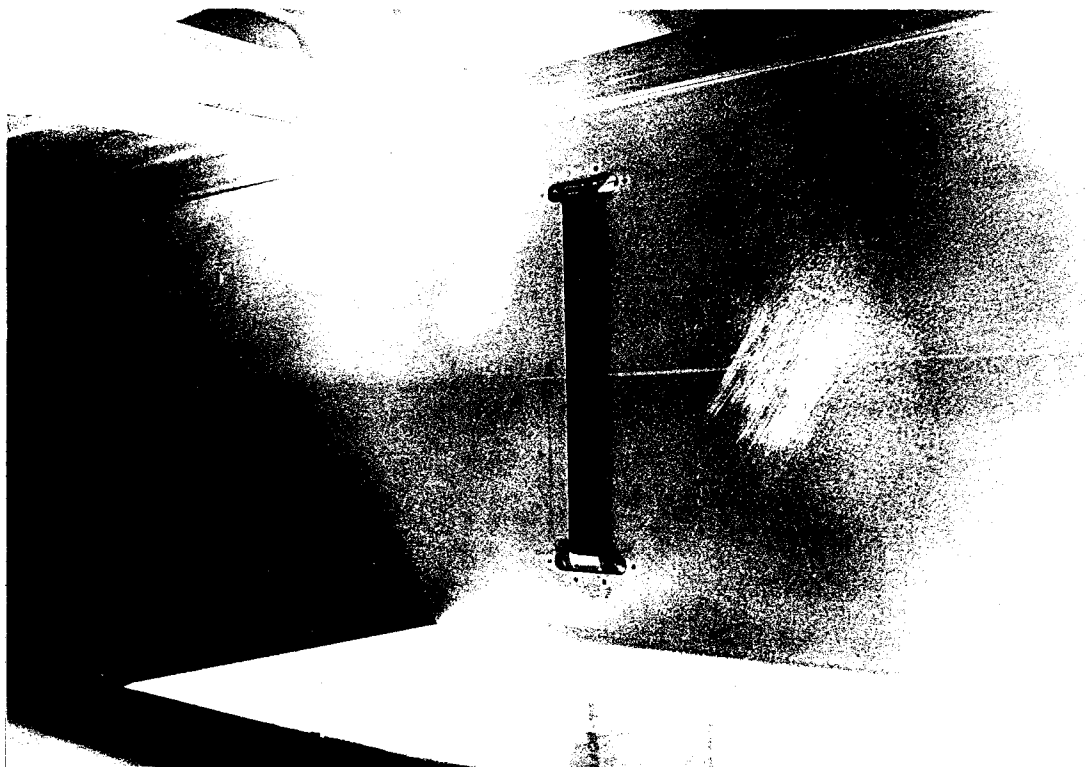


Figure 5-4 Le *lebu* fixé sur la plaque plane dans la soufflerie

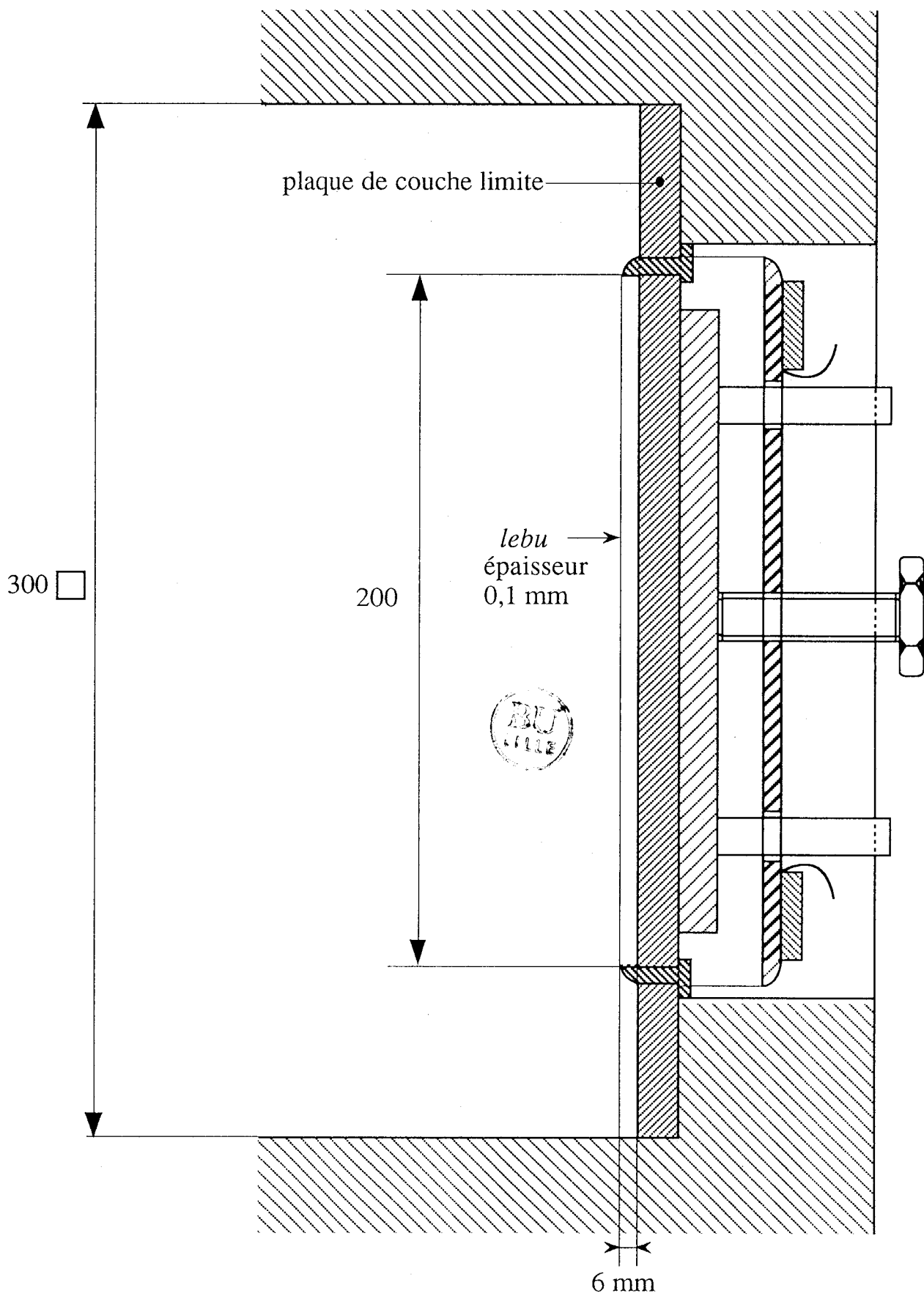


Figure 5-5 Montage du manipulateur dans la couche limite

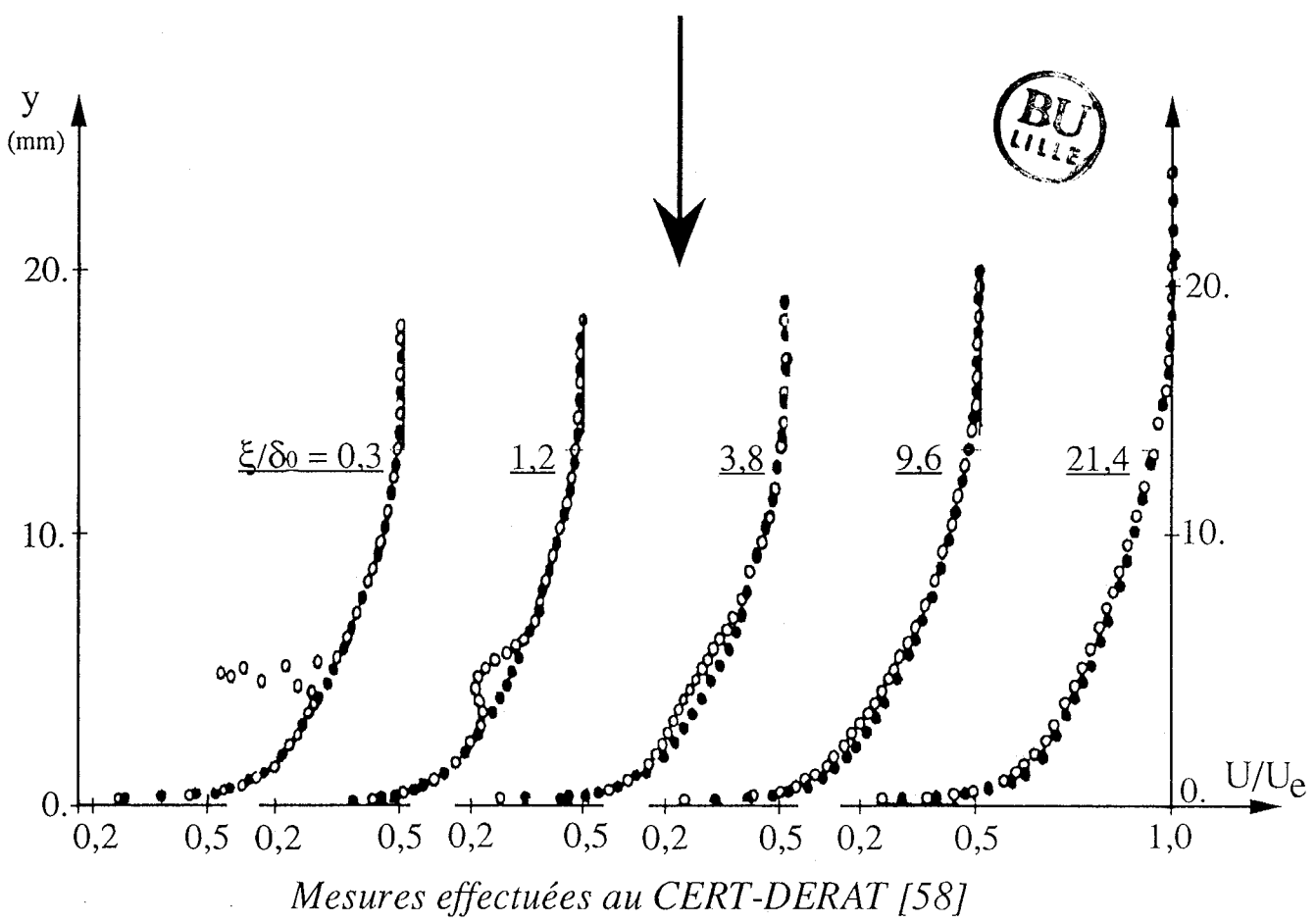
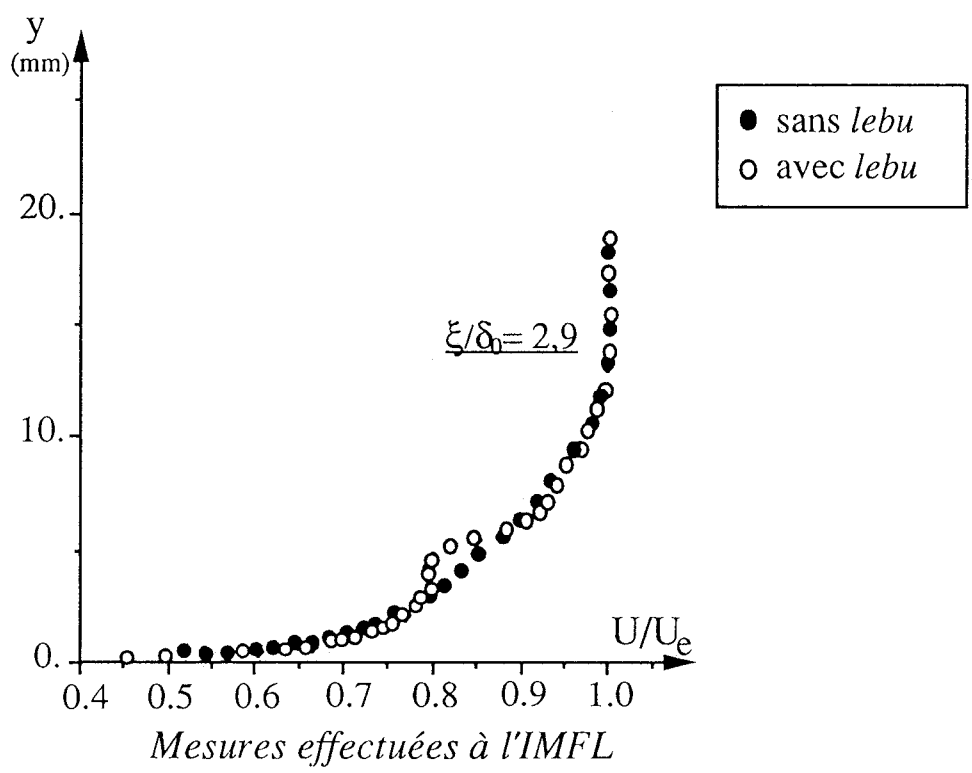


Figure 5-6 Comparaison des profils de vitesse moyenne avec et sans lebu

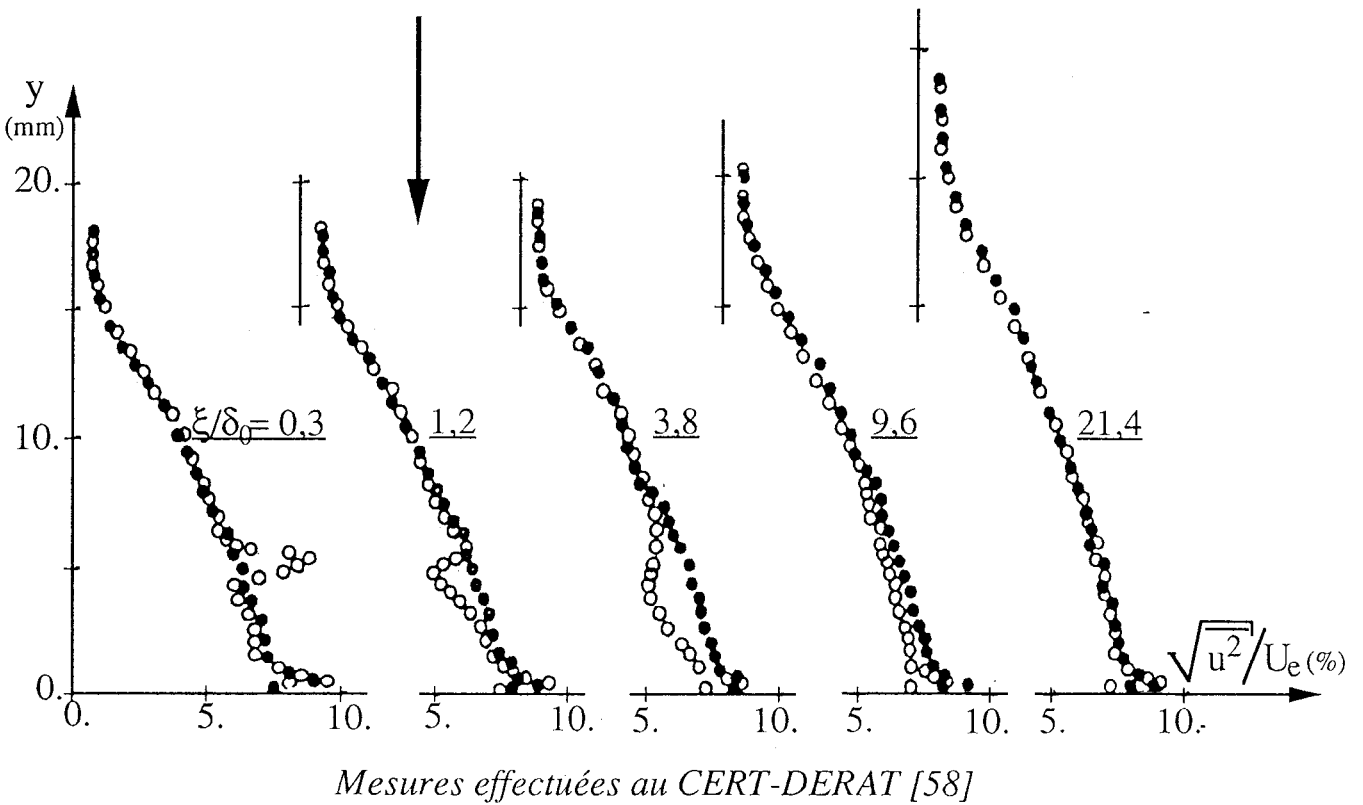
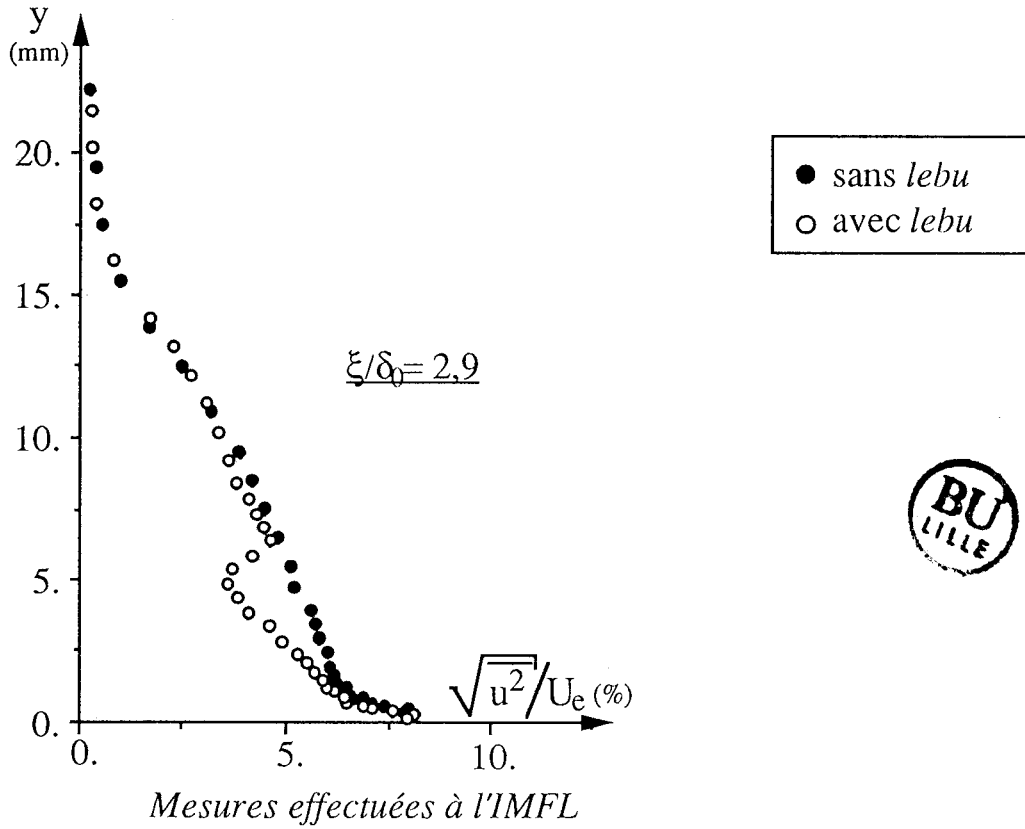


Figure 5-7 Comparaison des profils de la fluctuation longitudinale avec et sans lebu

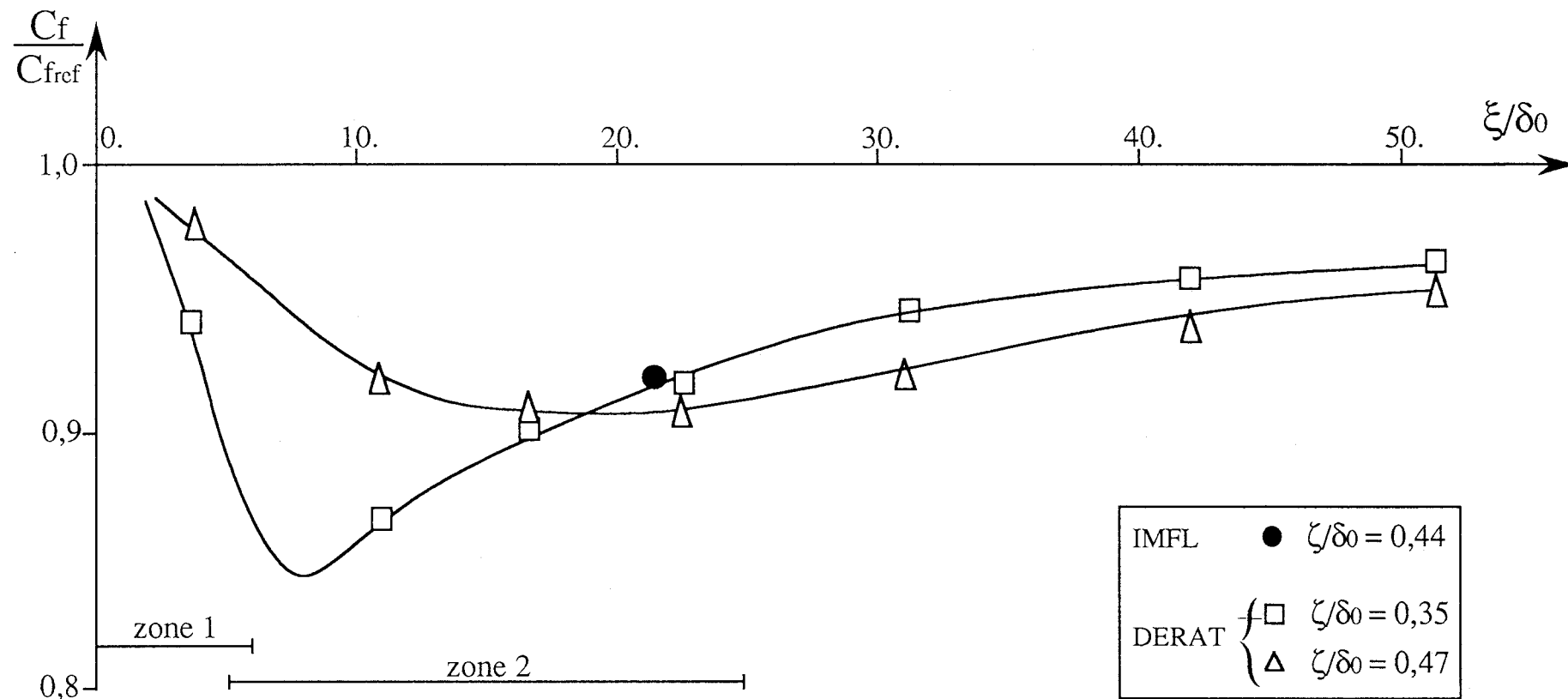


Figure 5-8 Coefficient de frottement à $\xi/\delta_0 \approx 20$ comparé aux résultats du DERAT [58]

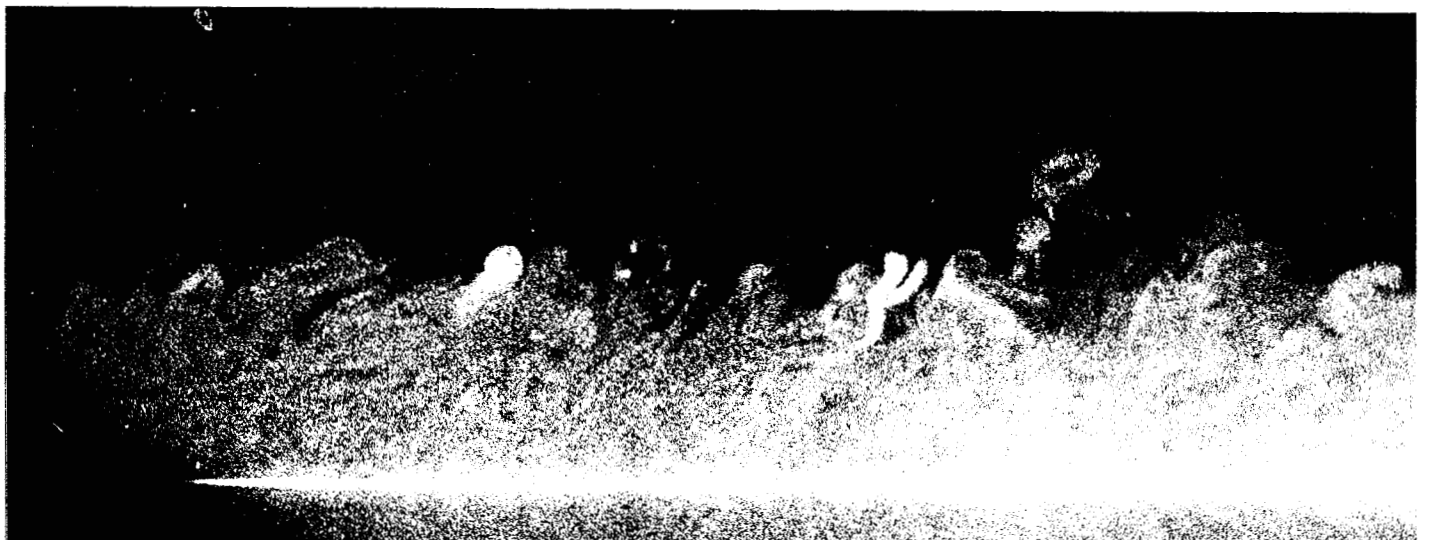
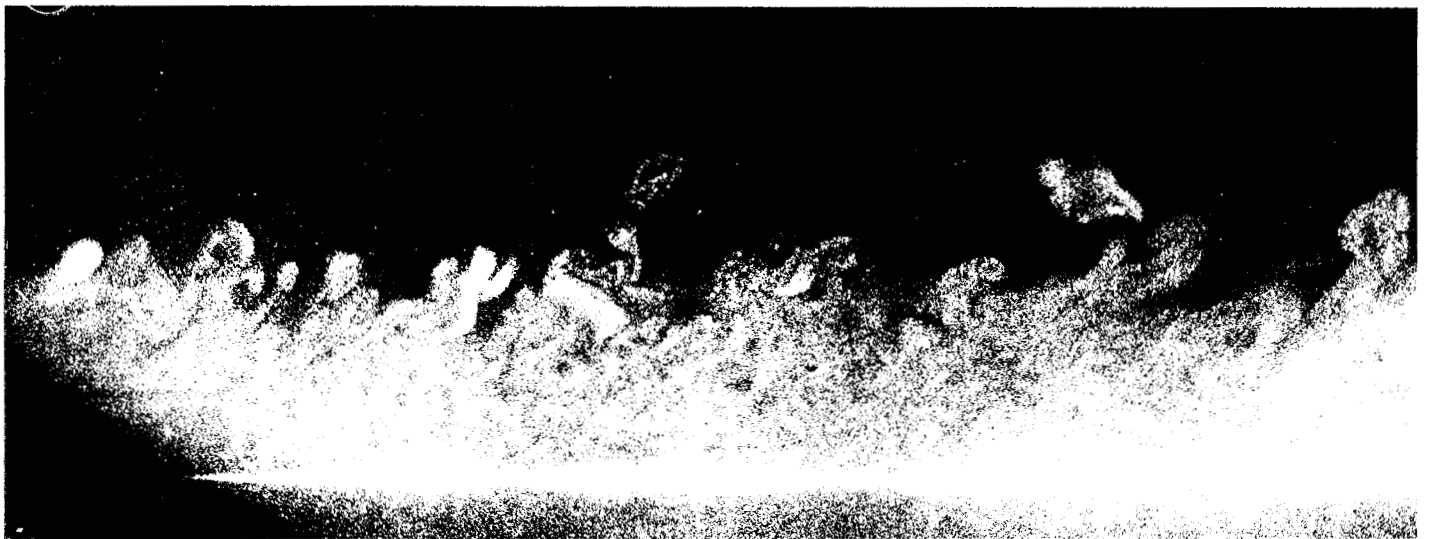
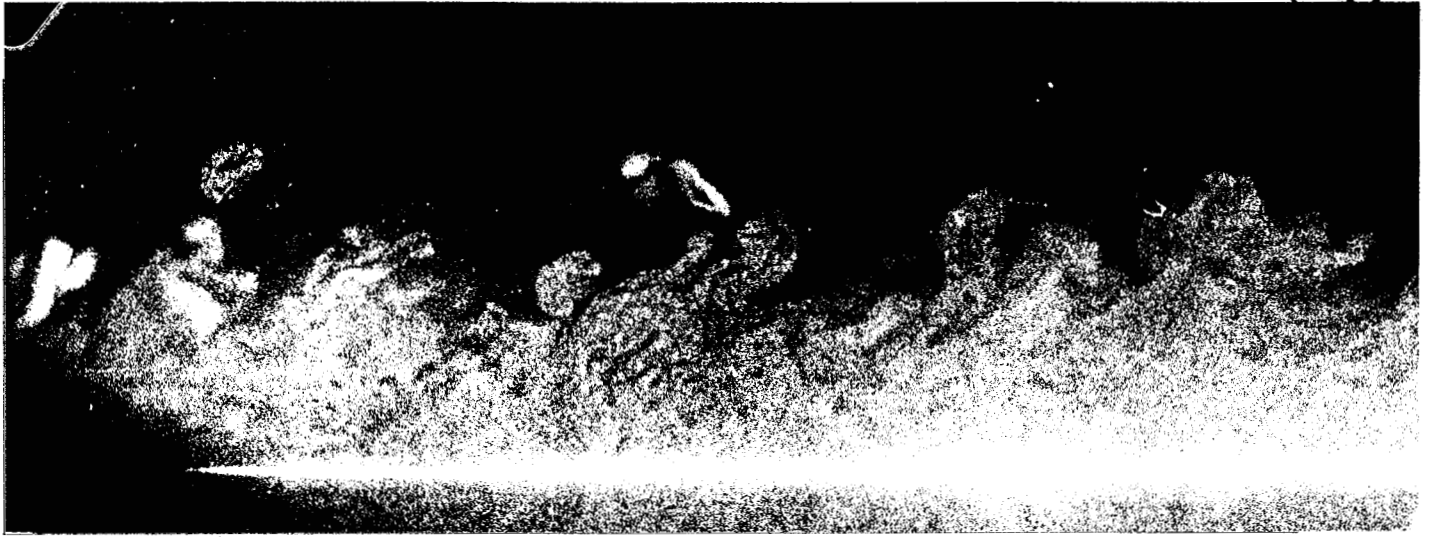


Figure 5-9 Prise de vues entre 0 et 6 δ_0 en présence du *lebu*
 $\Delta t = 1,3 \text{ ms}$ - $U_e = 22 \text{ m/s}$

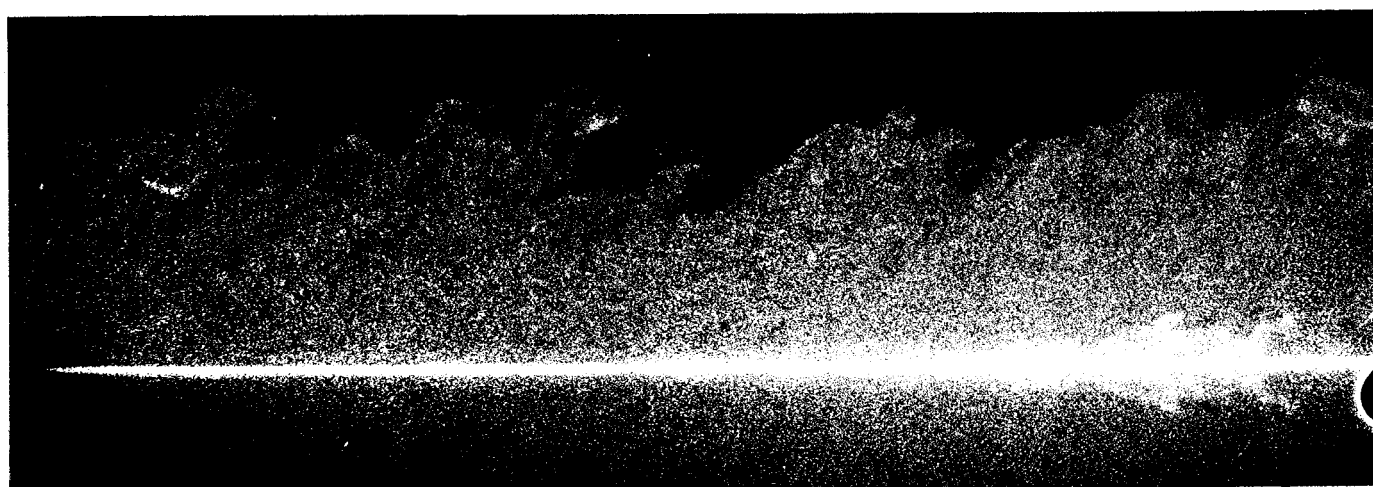
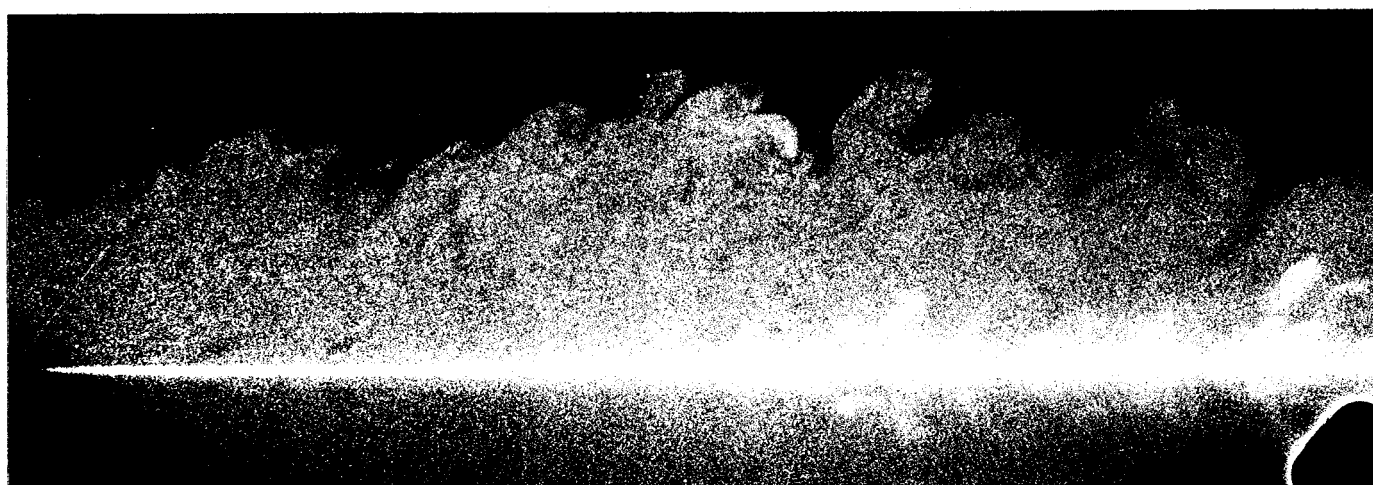
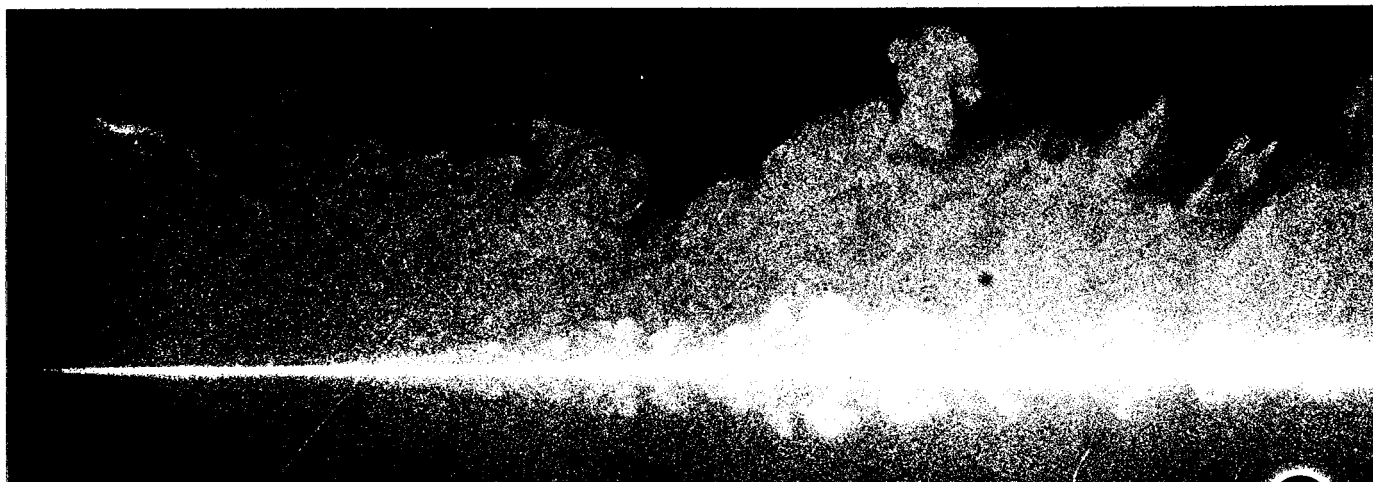
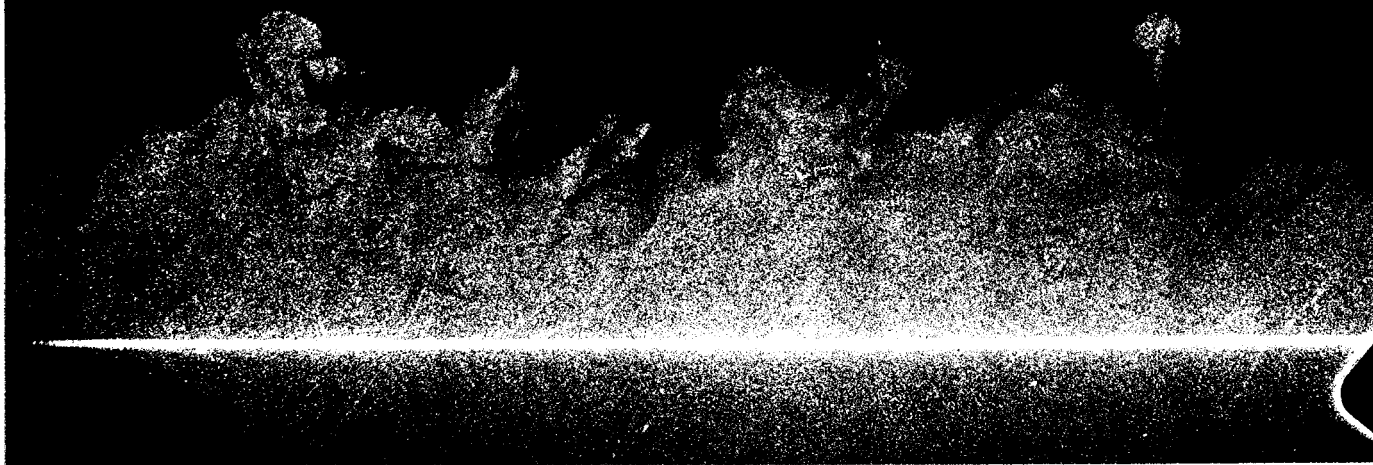


Figure 5-10 Prise de vues juste en aval du *lebu*
 $\Delta t = 1,9 \text{ ms} - U_e = 22 \text{ m/s}$

