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Hydraulic Turbines Cavitation

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Master Degree in Innovative Technologies in Energy Efficient Buildings
for Russian & Armenian Universities and Stakeholders

FORMES DIVERSES DES CAVITÉS DE VAPEUR

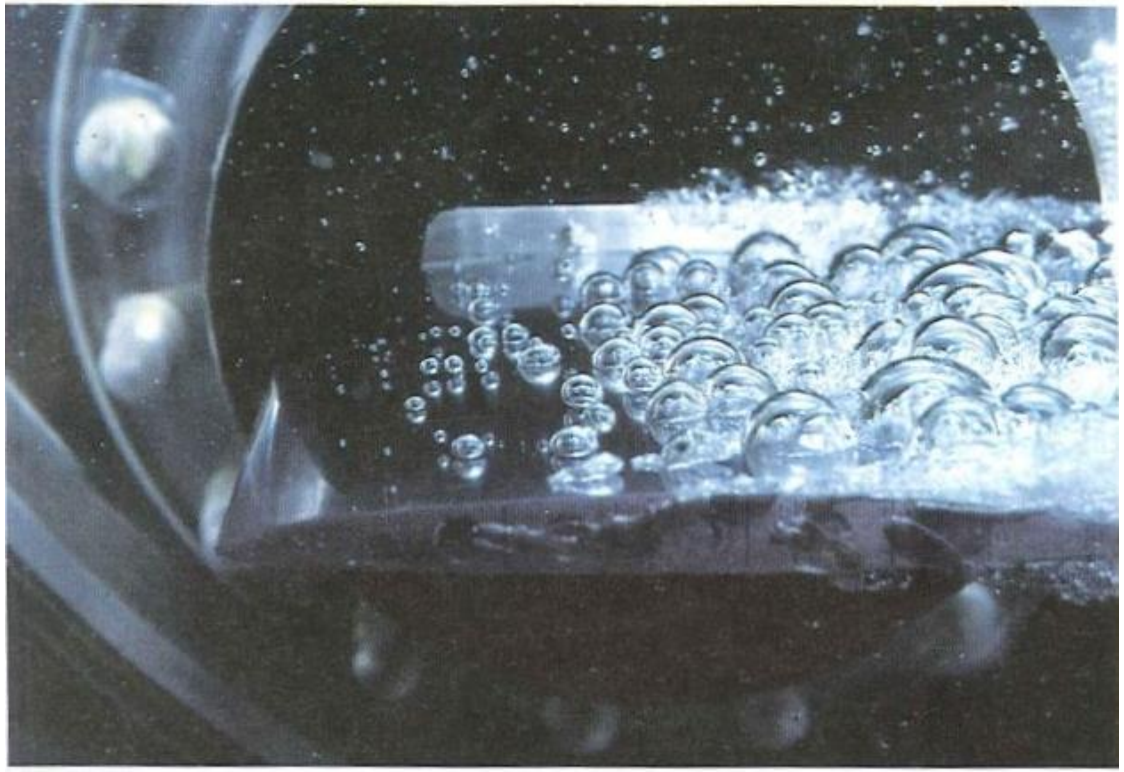
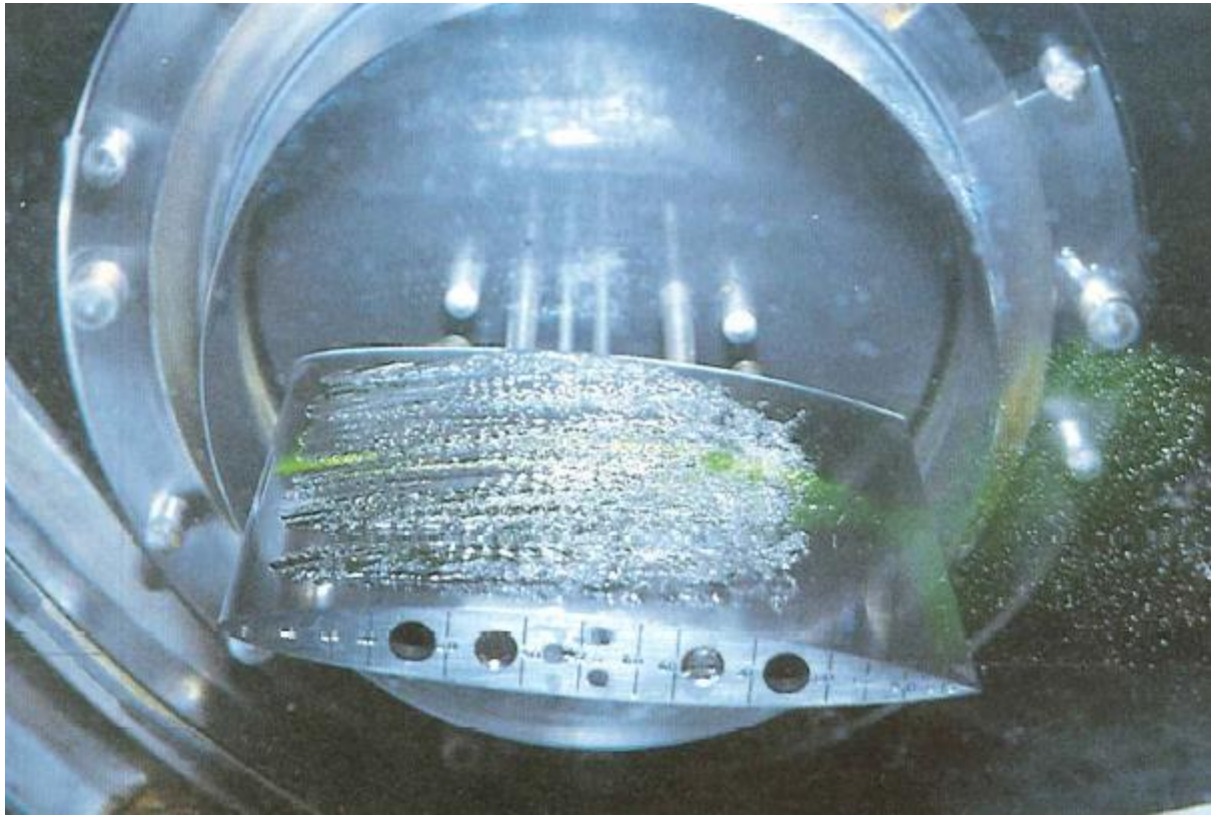


Fig. 1.3. Bulles sur un profil d'aile
(profil NACA 16-209 ; Re = 10^6 ; $\sigma_v = 0{,}07$; incidence : 0°)



Poche sur un profil d'aile: incidence 5°

FORMES DIVERSES DES CAVITÉS DE VAPEUR

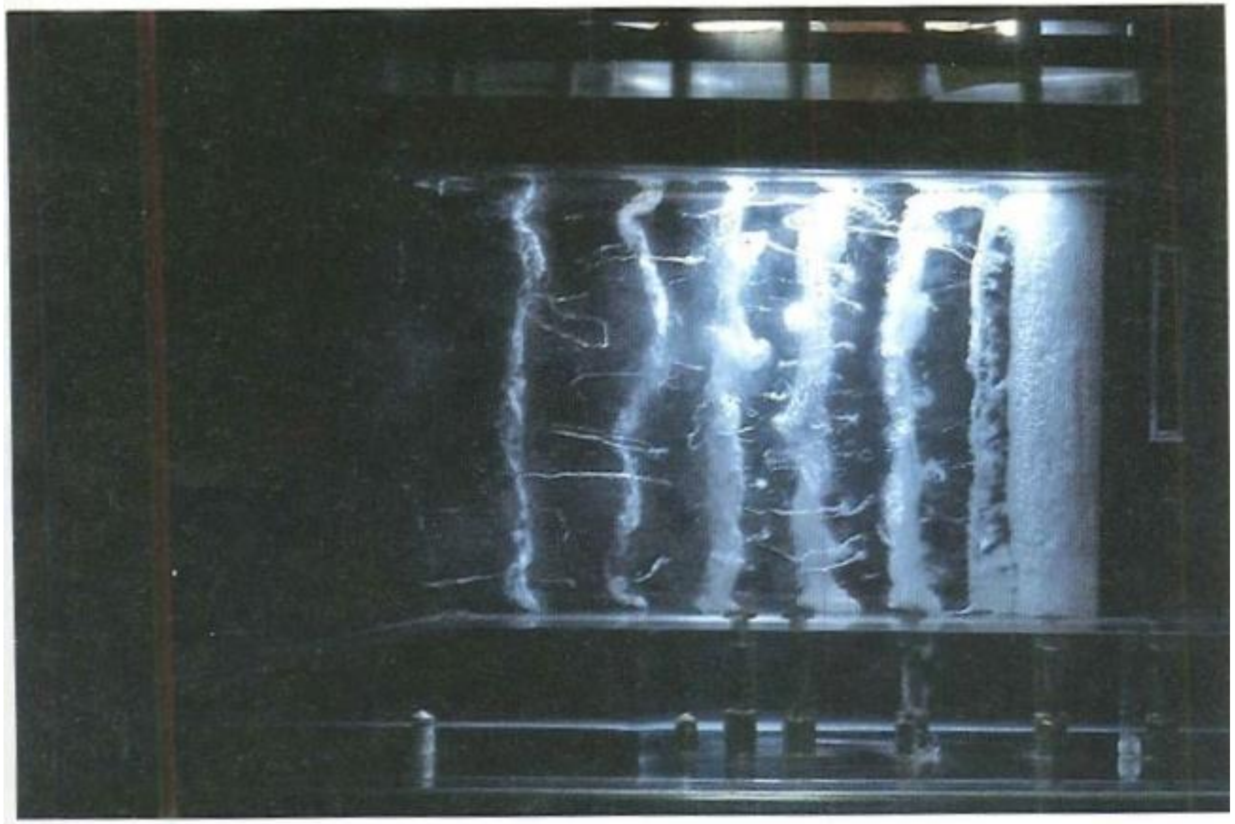
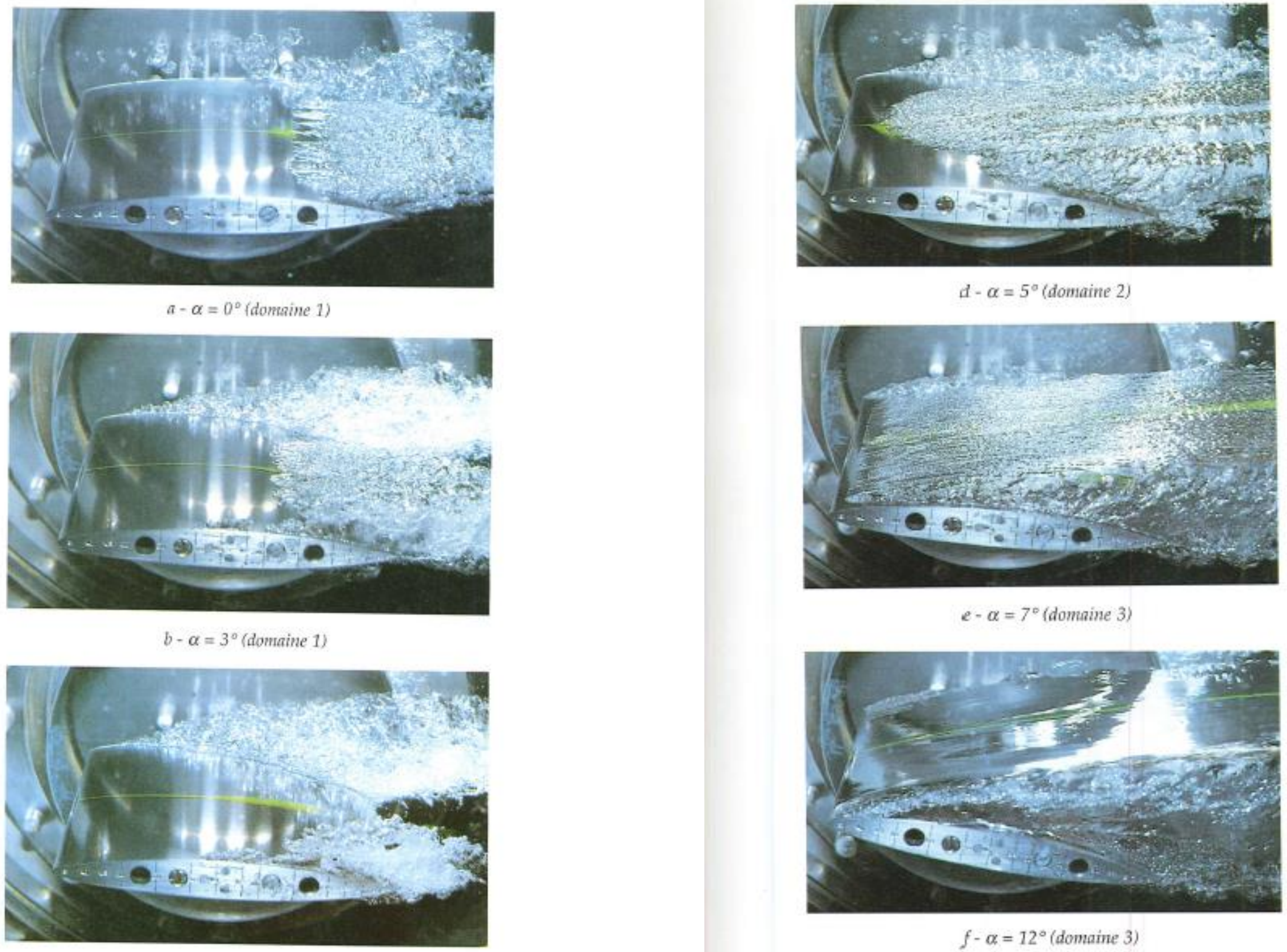


Fig. 1.5. Tourbillons cavitants dans un sillage

(profil : coin prismatique ; Re = $3{,}6.10^5$; $\sigma_v = 1{,}57$; $V = 10{,}8$ m/s ; écoulement de droite à gauche)

Tourbillon d'extrémité d'aile



a - $\alpha = 0°$ (domaine 1)

b - $\alpha = 3°$ (domaine 1)

c - $\alpha = 4°$ (domaine 2)

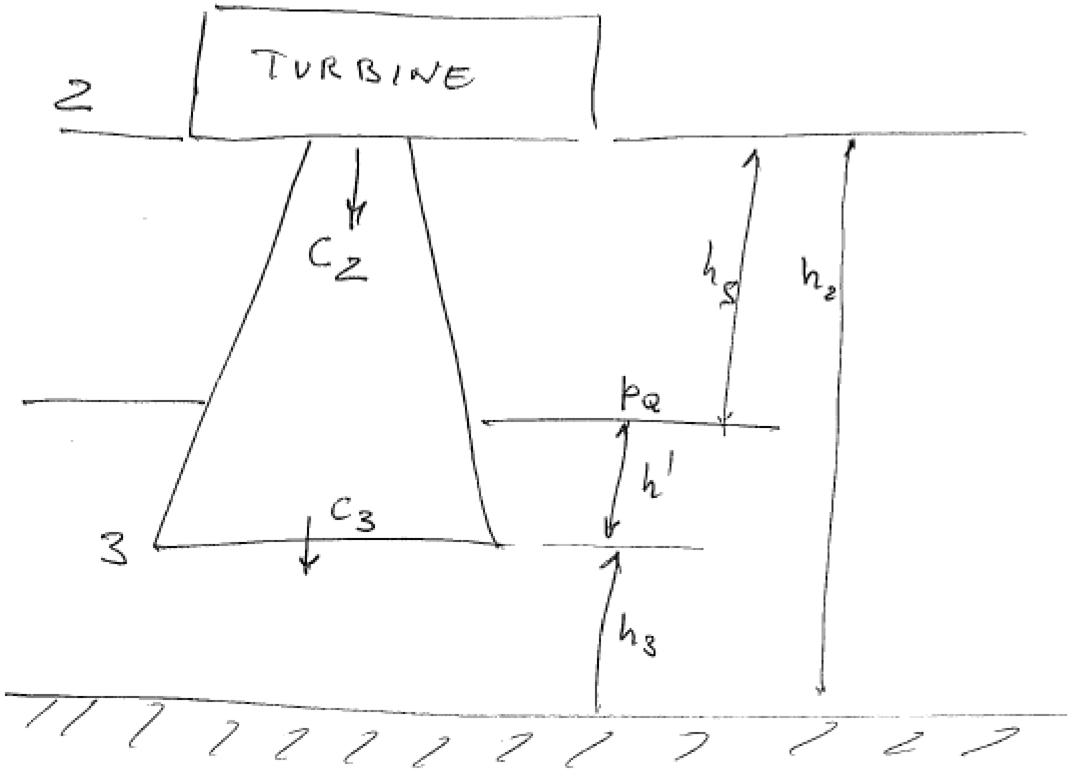
d - $\alpha = 5°$ (domaine 2)

e - $\alpha = 7°$ (domaine 3)

f - $\alpha = 12°$ (domaine 3)

Fig. 4.12. *Visualisation de la couche limite et de la cavitation par poche se développant à l'extrados d'un profil NACA 16-012 en fonction de l'incidence pour un nombre de Reynolds $Re = 6.10^5$ et un paramètre de cavitation $\sigma_v = 0{,}13$*

Hydraulic Turbine Diffuser



$$\frac{p_2}{\rho}+\frac{c_2^2}{2}+g h_2=\frac{p_3}{\rho}+\frac{c_3^2}{2}+g h_3+g h_{pd}$$

$$\frac{p_3}{\rho}=\frac{p_a}{\rho}+g h' \qquad h'+h_3=(h_2-h_s)$$

$$\frac{p_2}{\rho}\cancel{+}\frac{c_2^2}{2}+g h_2=\frac{p_a}{\rho}+\frac{c_3^2}{2}+g(h_2-h_s)+g h_{pd}$$

$$\frac{p_2}{\rho}=\frac{p_a}{\rho}-g h-\frac{\left(c_2^2-c_3^2\right)}{2}+g h_{pd}$$

$p_2 < p_a$ for head (suction) and Kinetic energy recovery

But to avoid cavitation: ②c

$$\frac{p_2}{\gamma} = \frac{p_a}{\gamma} - h_s - \frac{(c_2^2 - c_3^2)}{2g} + h_p \geq \frac{p_v}{\gamma}$$

In the turbine in reality

$$p_{min} < p_2$$

$$\frac{p_{min}}{\gamma} = \frac{p_2}{\gamma} - \lambda \frac{w^2}{2g}$$ therefore

$$\frac{p_a}{\gamma} - h_s - \frac{c_2^2 - c_3^2}{2} + h_p - \frac{\lambda w^2}{2g} \geq \frac{p_v}{\gamma}$$

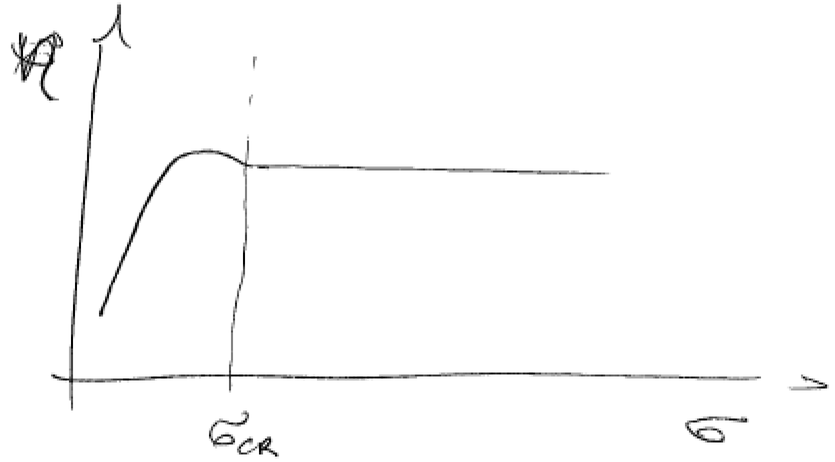
$$\frac{p_a}{\gamma} - \frac{p_v}{\gamma} - h_s \geq \frac{c_2^2 - c_3^2}{2} + \frac{\lambda w^2}{2g} - h_p$$

$$NPSH_{plant} \geq NPSH_{CRITICAL}$$ (required)

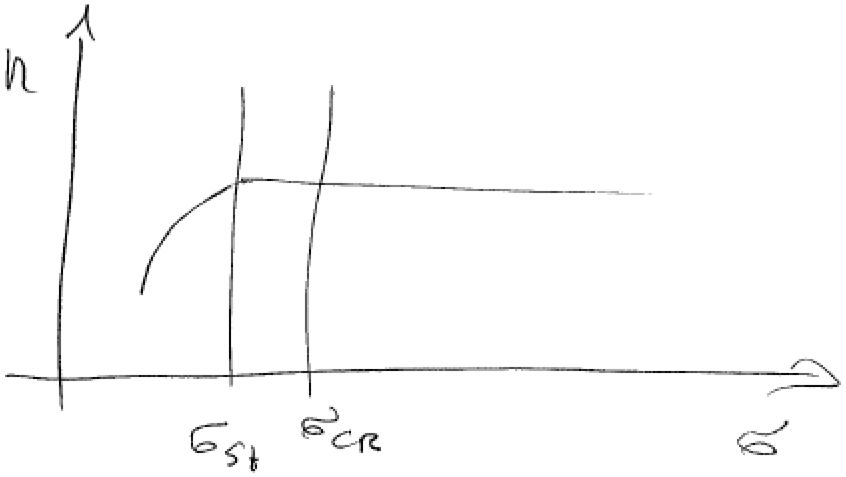
$$\frac{NPSH}{H}_{plant} \geq \frac{NPSH_{crit.}}{H}$$

$$\sigma_{plant} \geq \sigma_{CR}$$

σ_{CR} is experimentally determined by cavitation tests for the turbine and finally h_s (suction head) can be calculated in order to avoid cavitation.



or



or and strobo - tests

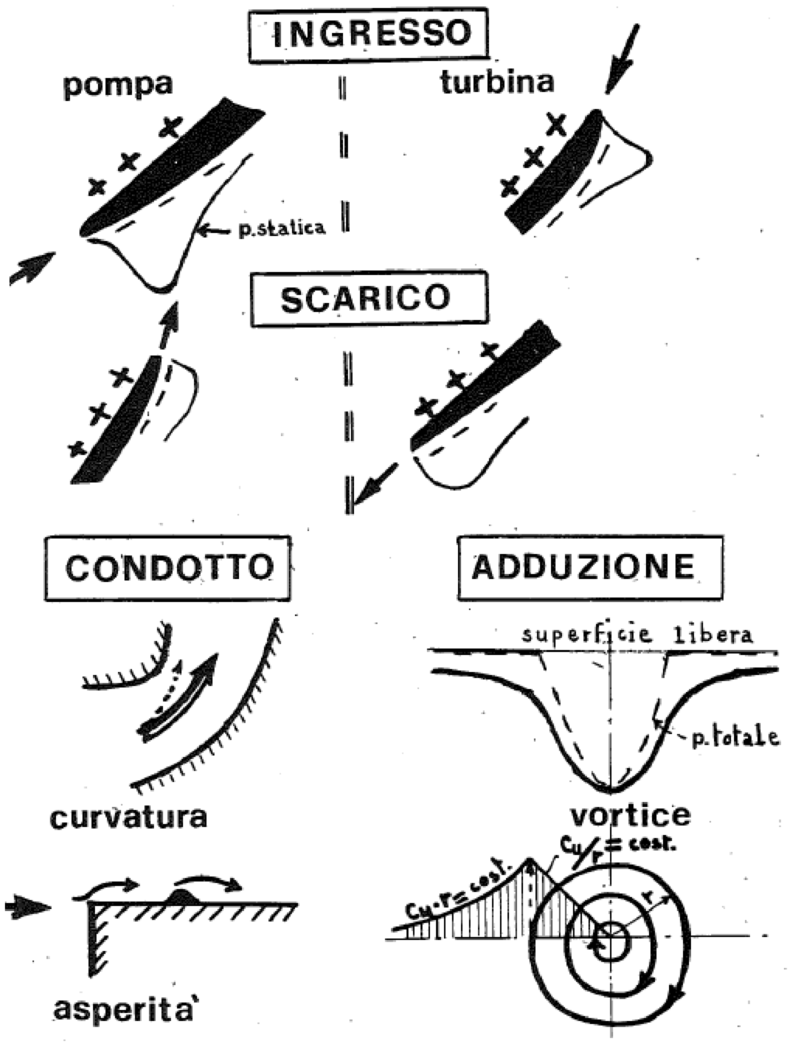


Fig. 3.1. Alcune forme di diminuzione della pressione locale nelle turbomacchine.

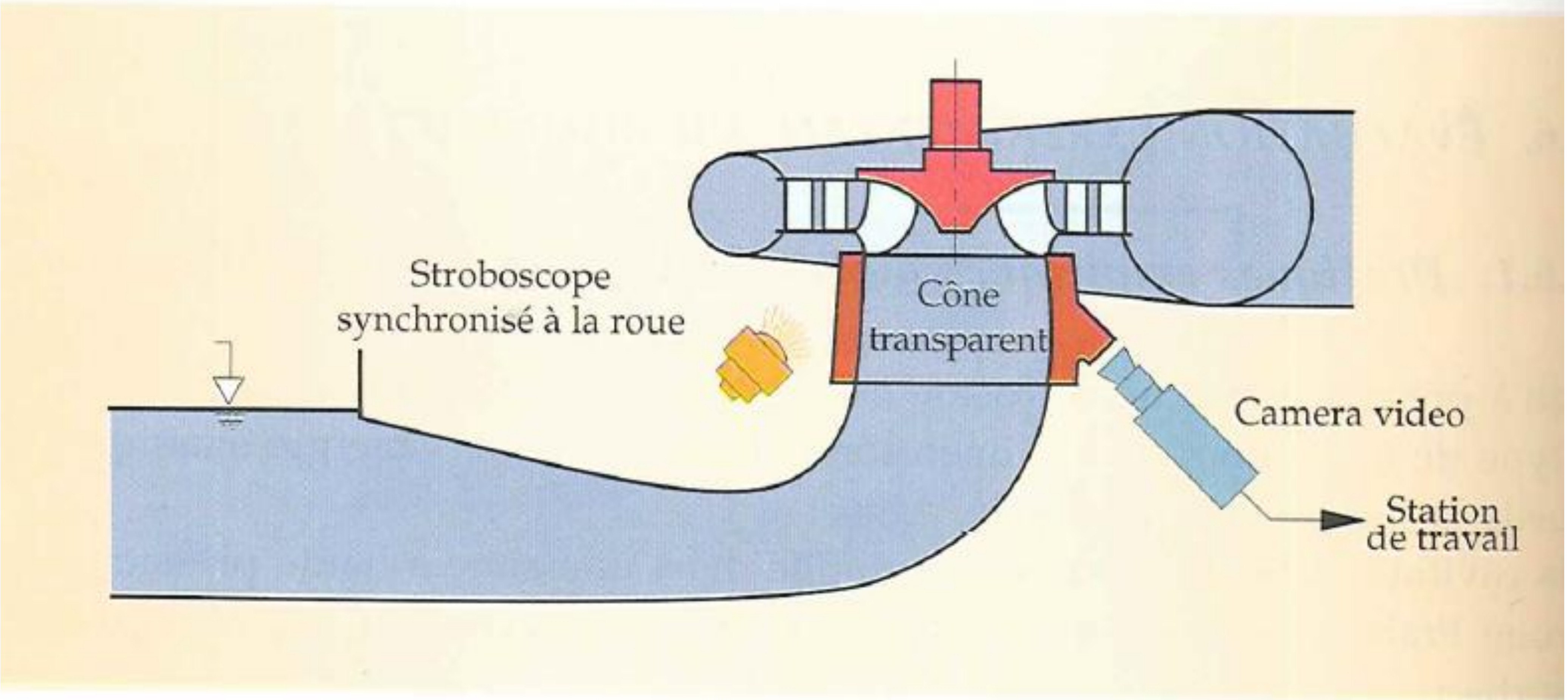
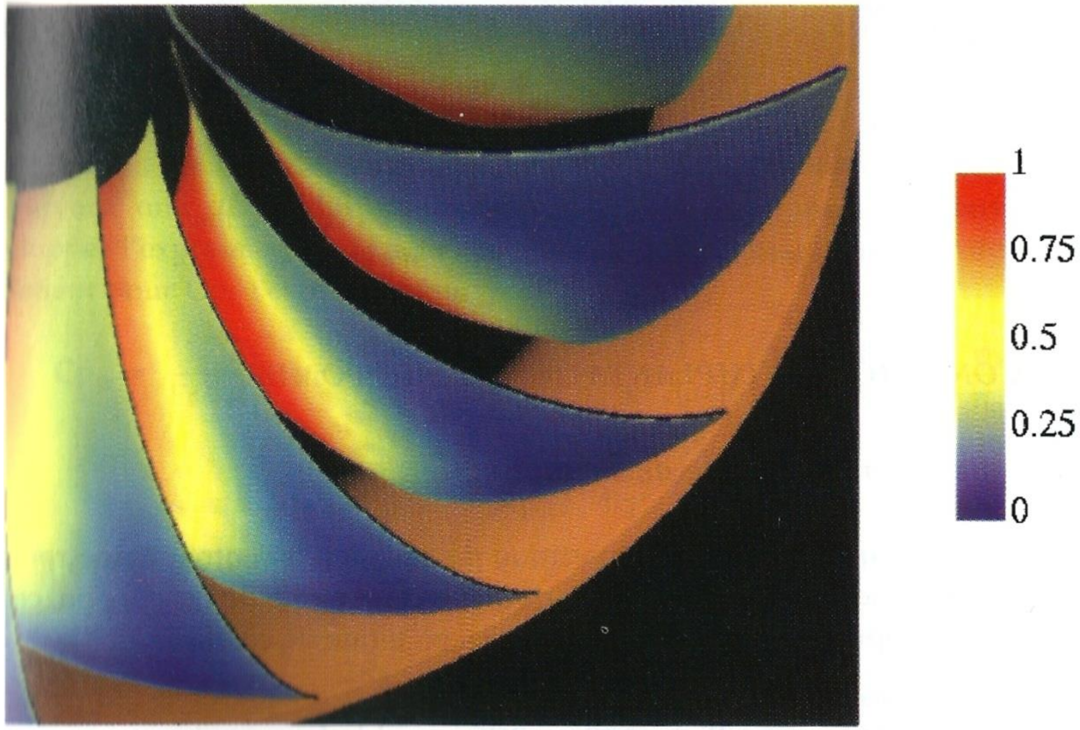


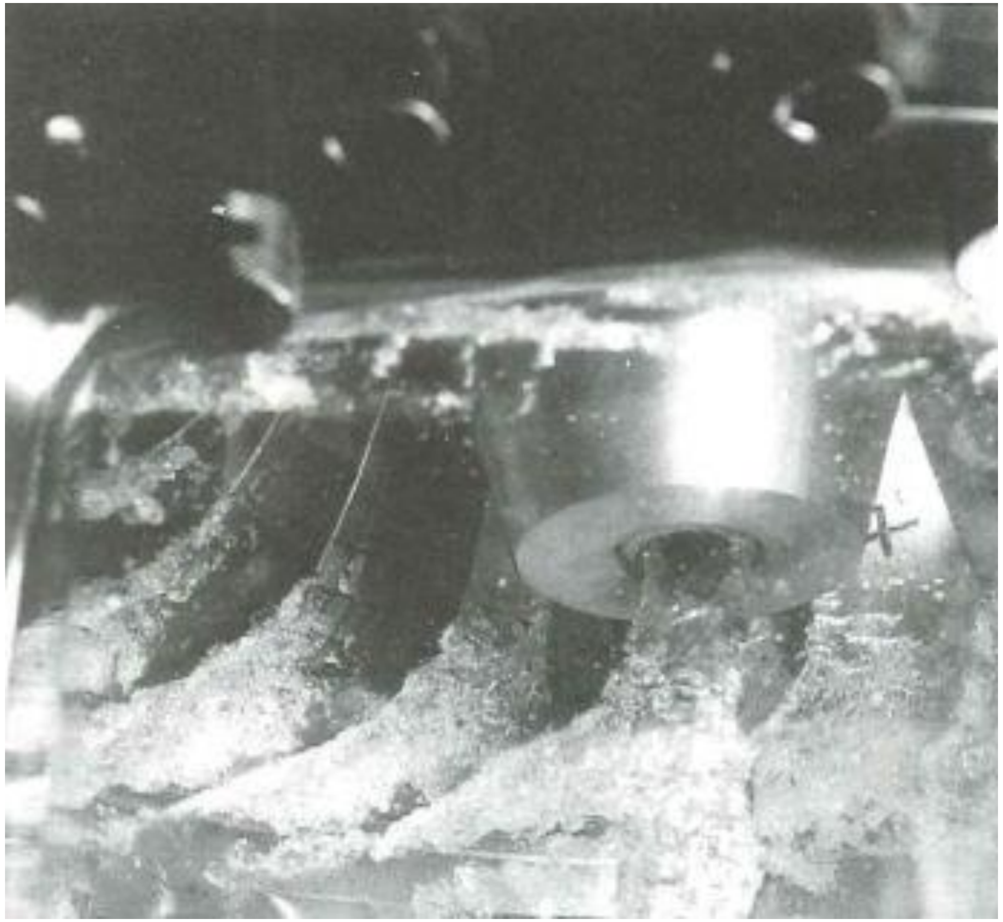
Fig. 9.41. Système vidéo de visualisation des cavités



9.15. *Distribution de pression sur l'aubage d'une roue Francis (ν = 0,500). Résultats*

Fig. 9.16. Développement d'une cavité à l'entrée d'une roue de turbine Francis (ν = 0,500) (Avellan et al. 1993)

ig. 9.48. *Cavitation d'entrée dans une roue de turbine Francis*



Cavitation de sortie

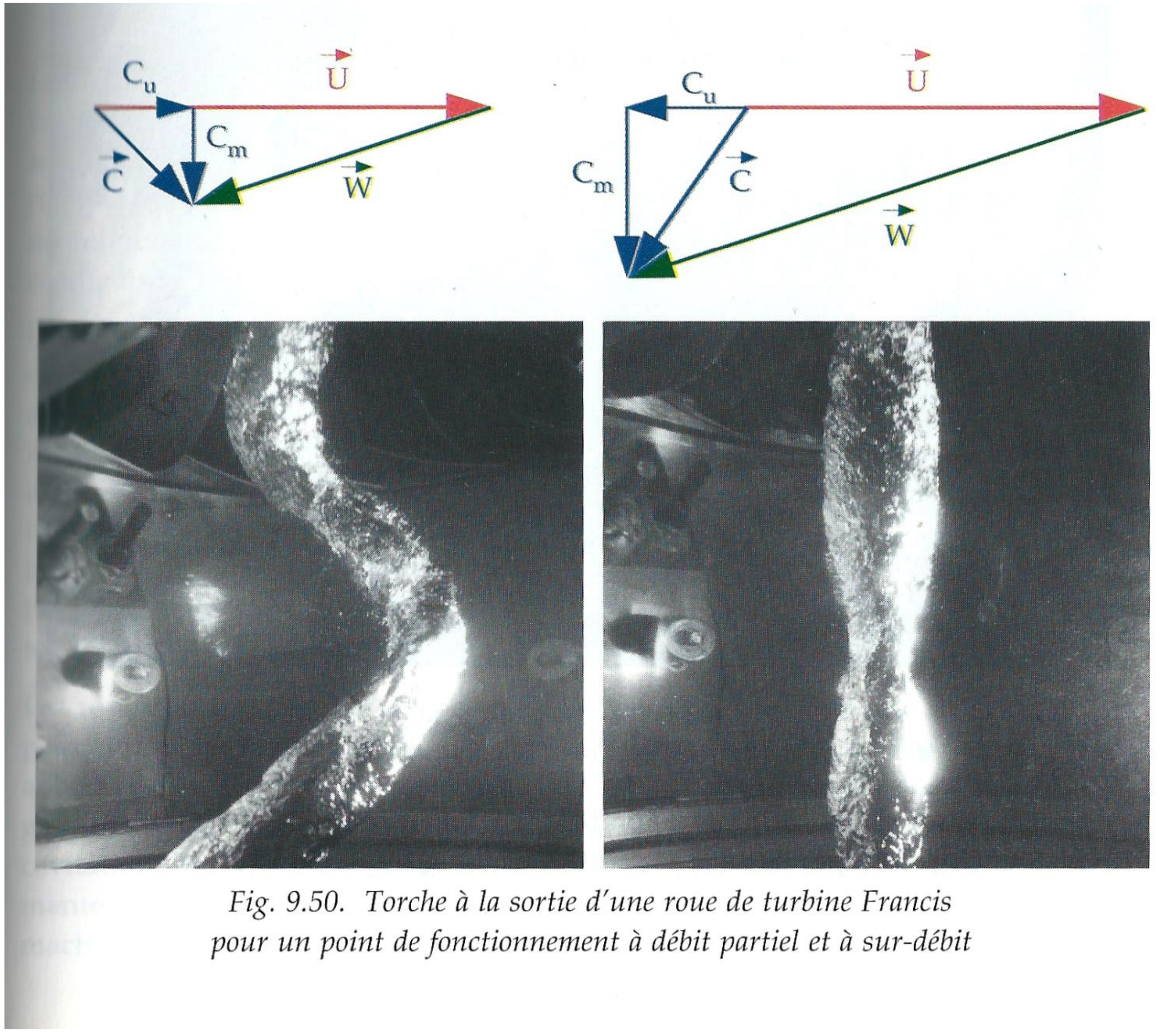


Fig. 9.50. Torche à la sortie d'une roue de turbine Francis pour un point de fonctionnement à débit partiel et à sur-débit

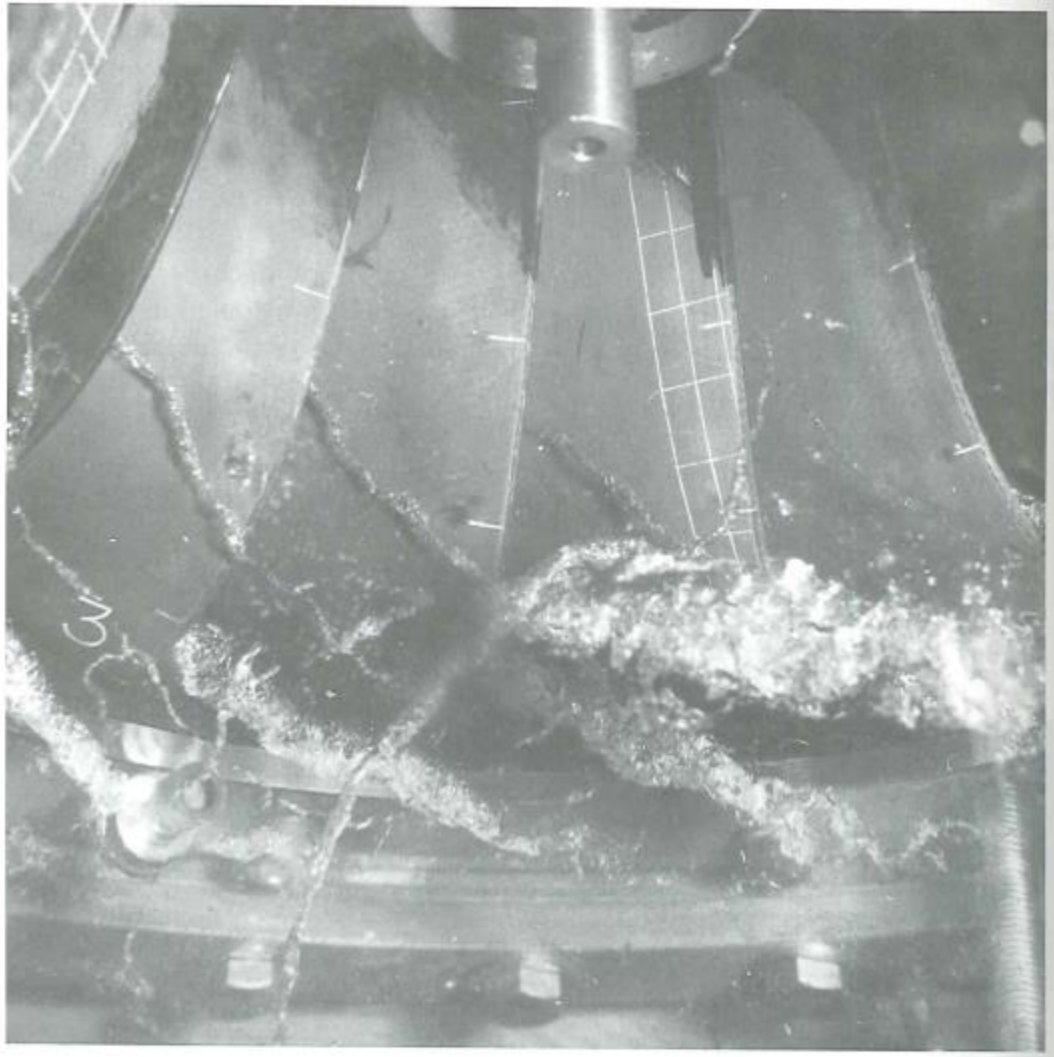


Fig. 9.51. Tourbillons de vapeur de charge partielle dans le canal interaubes d'une roue de turbine Francis

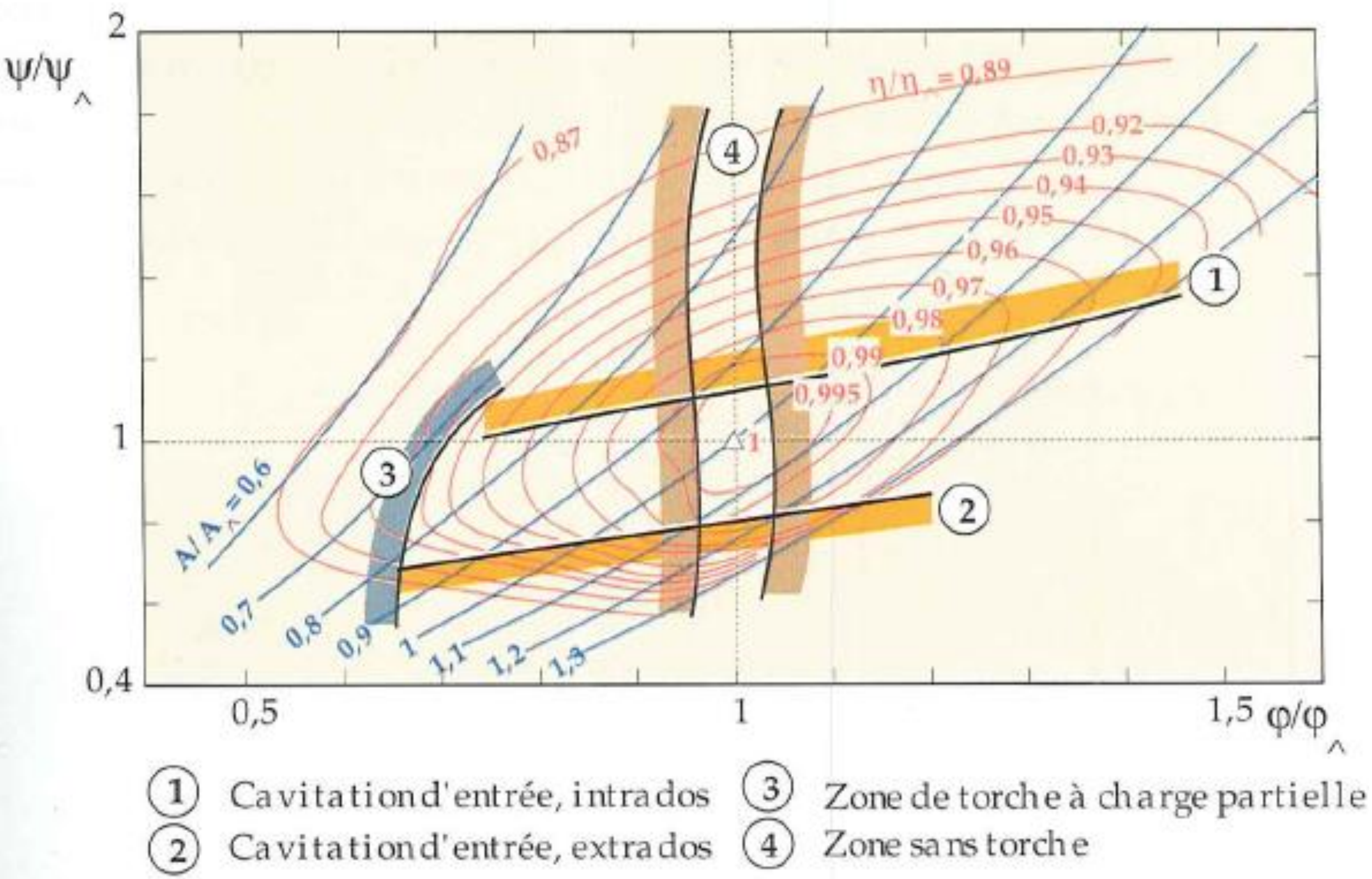


Fig. 9.52. Limite d'apparition des différents types de cavitation d'une Turbine Francis

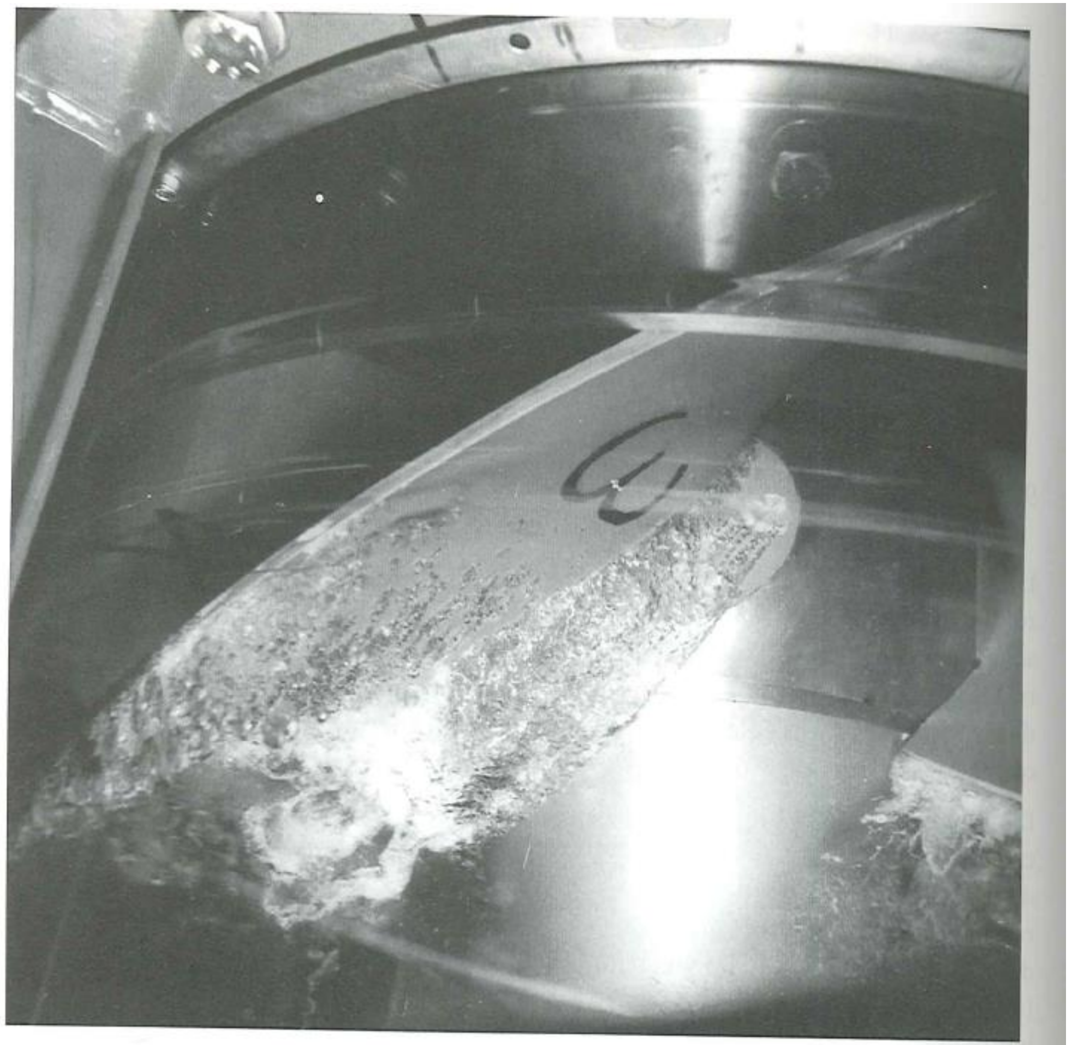


Fig. 9.53. *Développement de cavités dans la roue d'une turbine Kaplan*

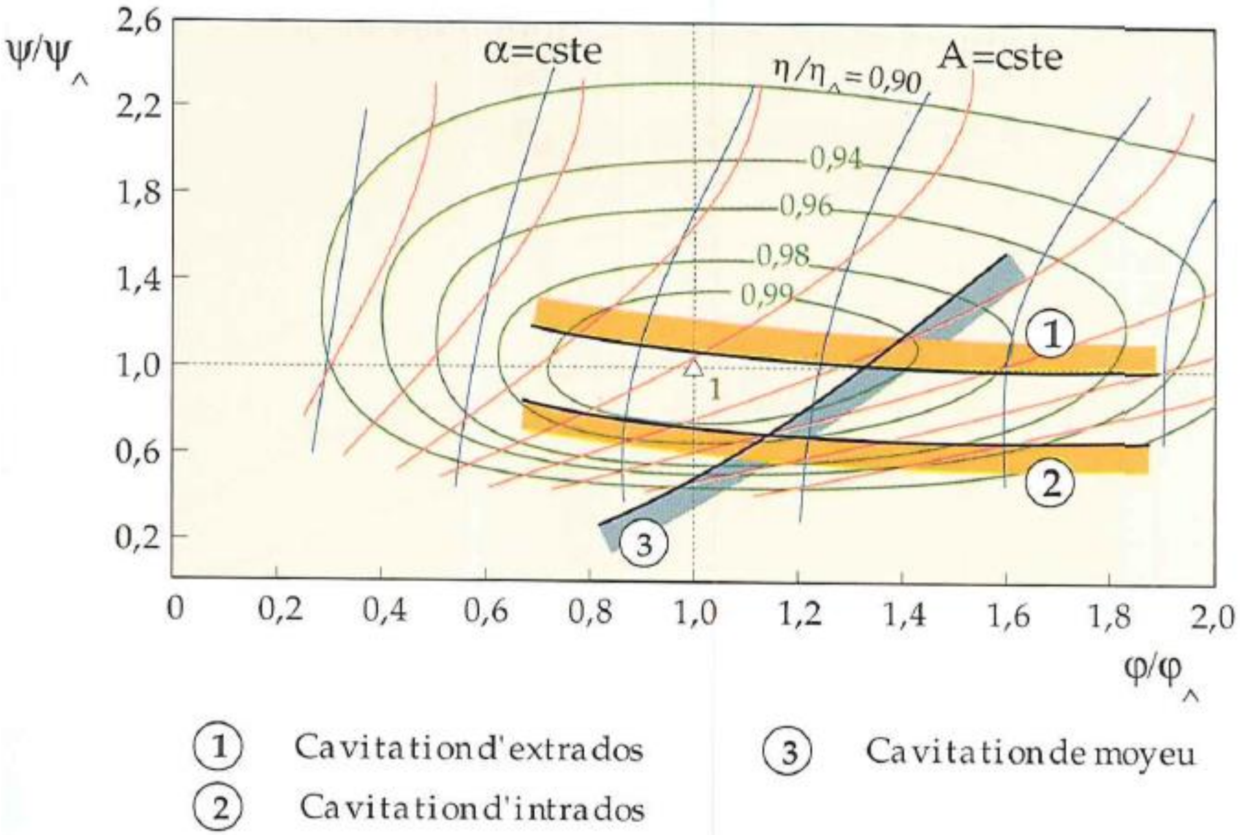


Fig. 9.54. Colline de rendement d'une turbine Kaplan

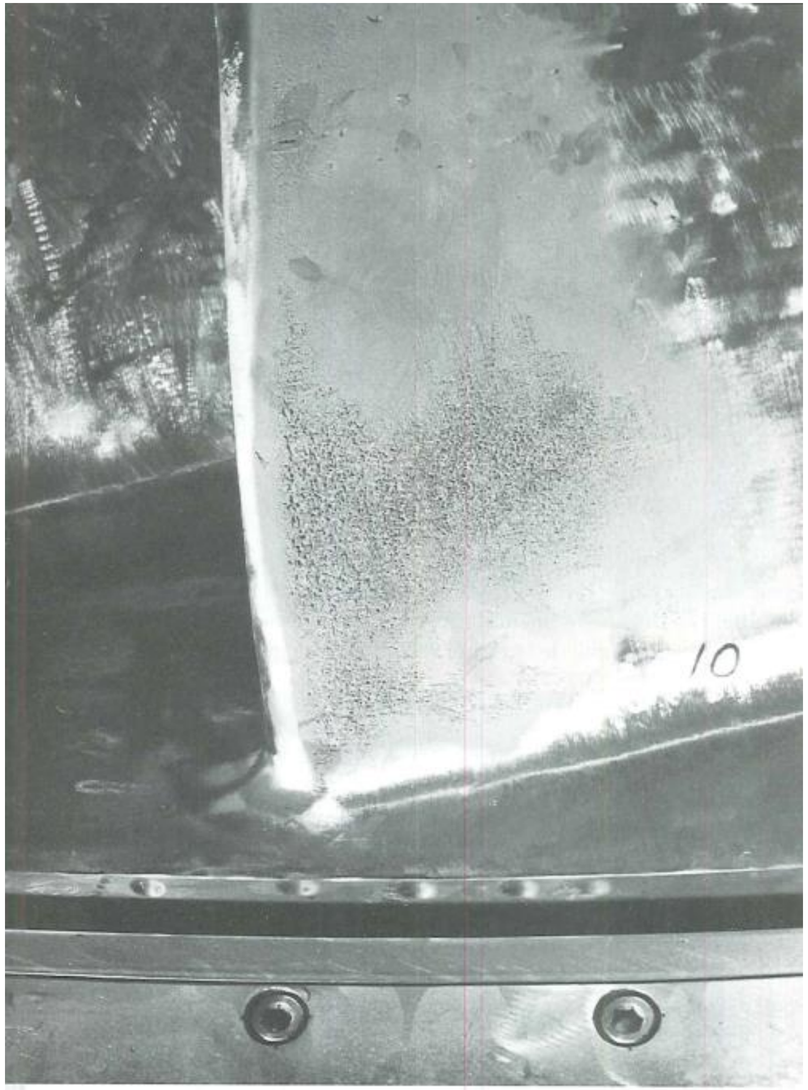
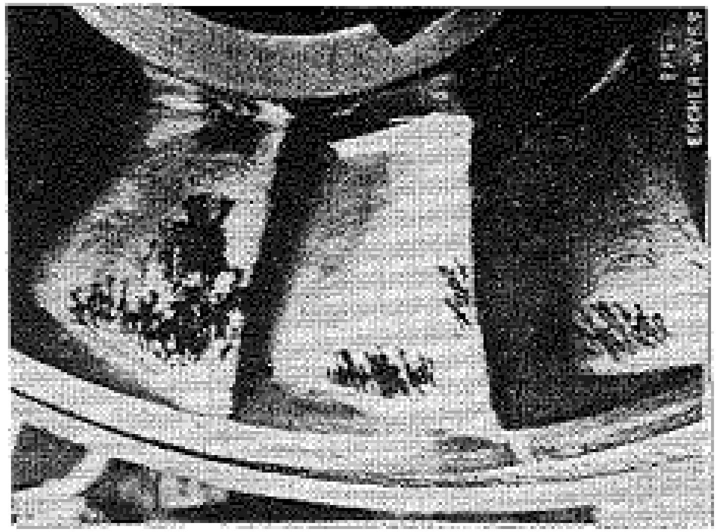
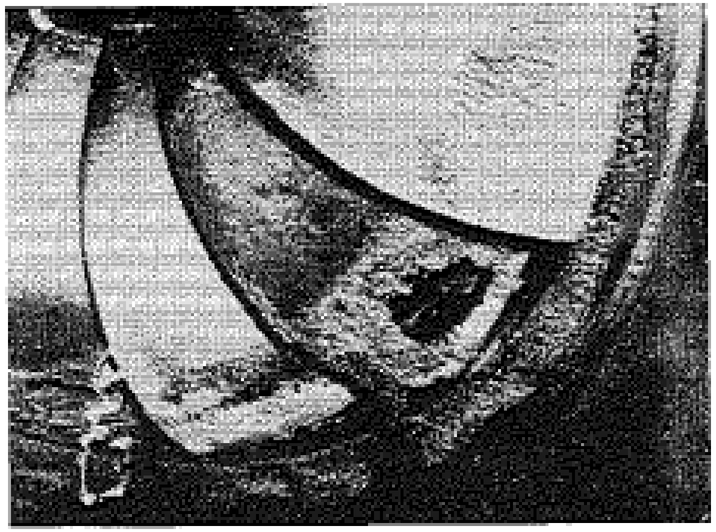


Fig. 9.80. Érosion en sortie d'aubage de roue d'une turbine Francis due à la cavitation à bulles séparées





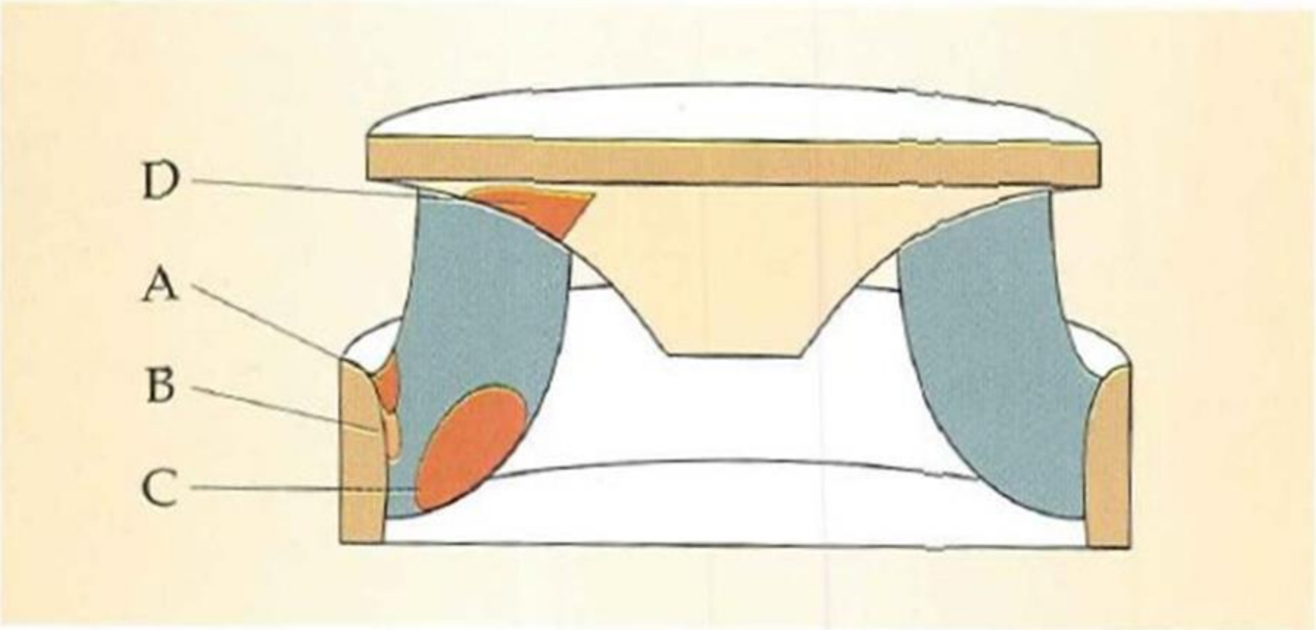
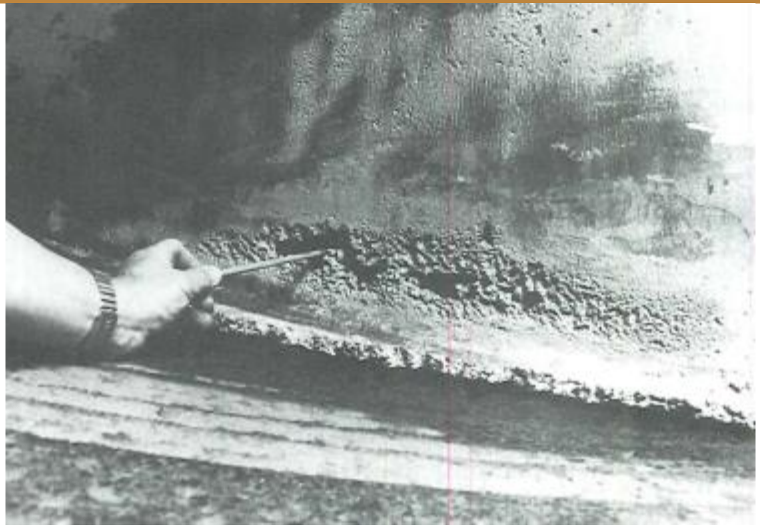


Fig. 9.77. Emplacements des zones de dégâts les plus fréquemment rencontrés dans une roue de turbine Francis



Erosion d'une aube de roue Kaplan due à la cavitation marginale

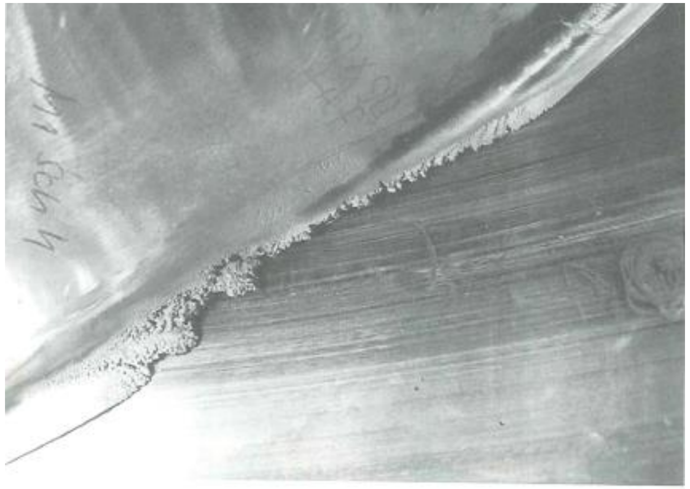


Fig. 9.85. Destruction de la collerette de bout de pâle d'une roue Kaplan

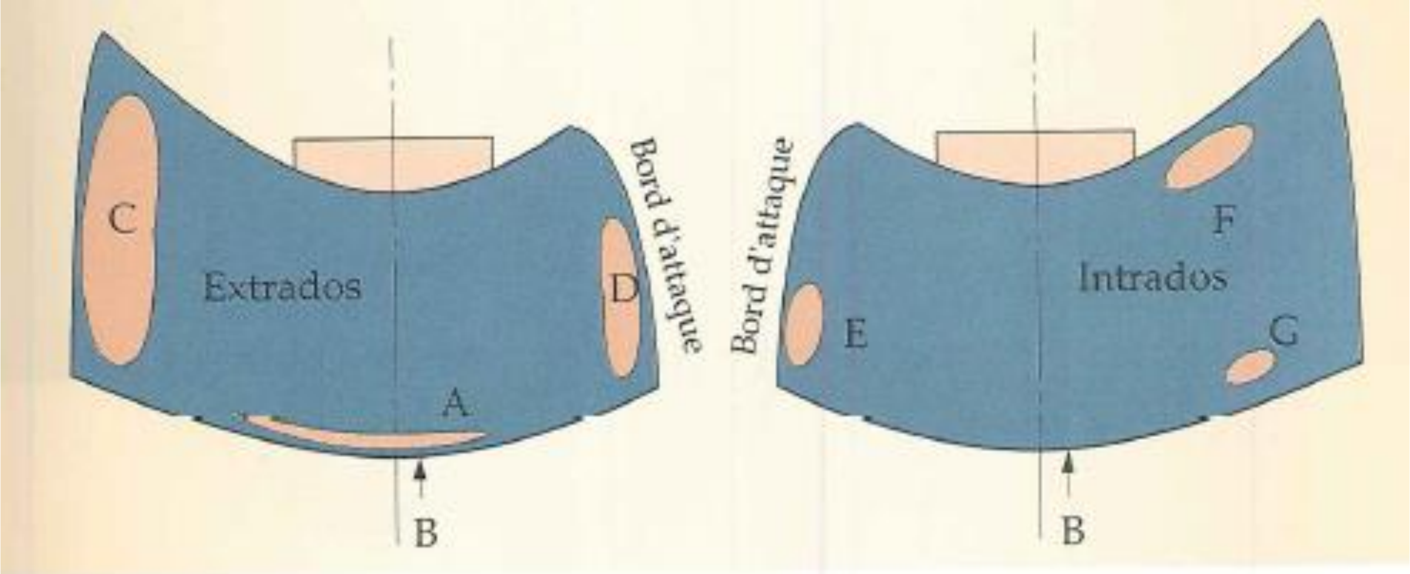


Fig. 9.83. Emplacement des zones de dégâts les plus fréquemment rencontrées dans une roue axiale, turbines Kaplan, hélices ou bulbes

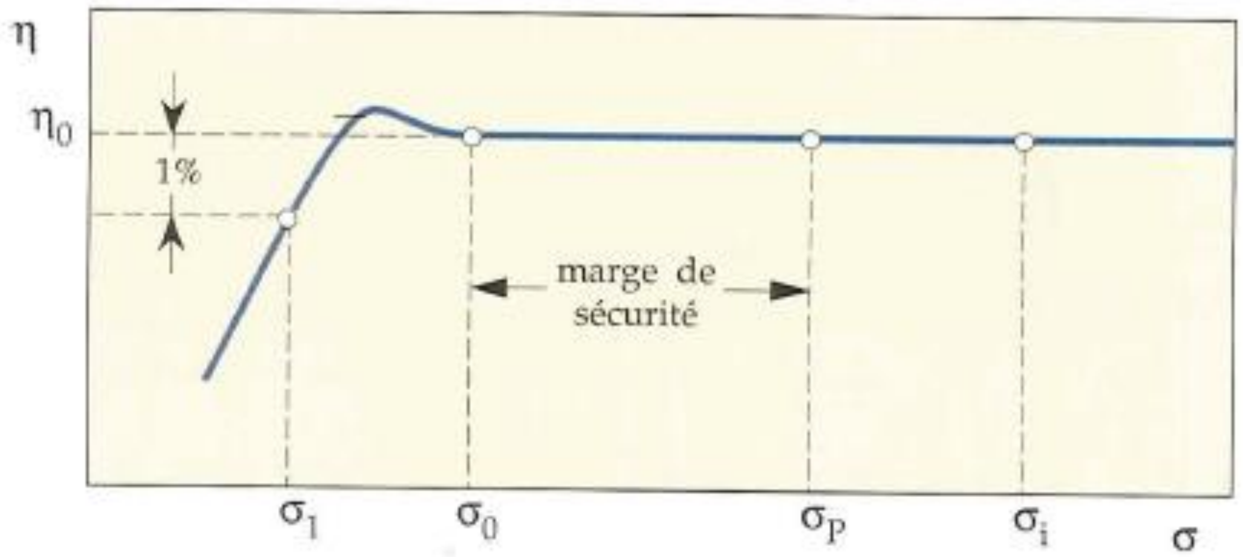
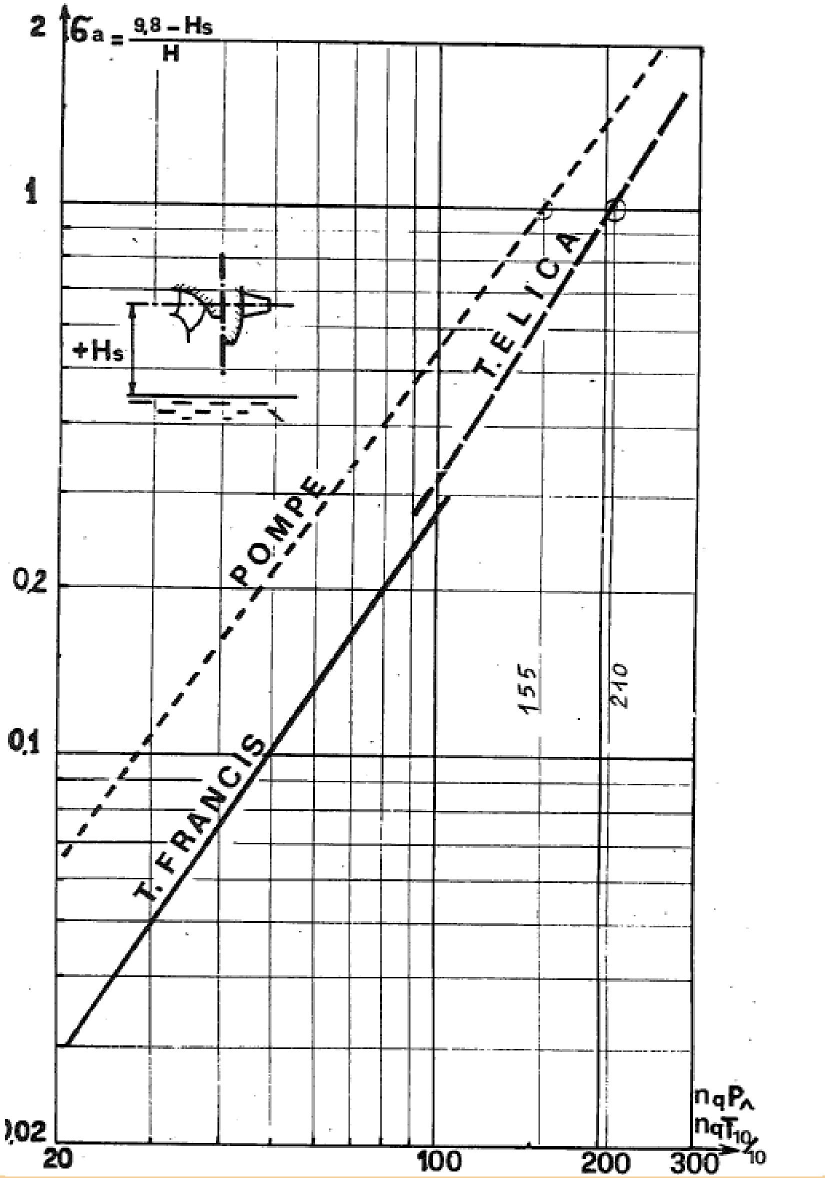


Fig. 9.31. Valeurs remarquables du nombre de Thoma


2
σa = (9,8 − Hs) / H
1
0,2
0,1
0,02
+Hs
POMPE
T. FRANCIS
T. ELICA
155
210
20
100
200
300
nqPA
nqT10/10

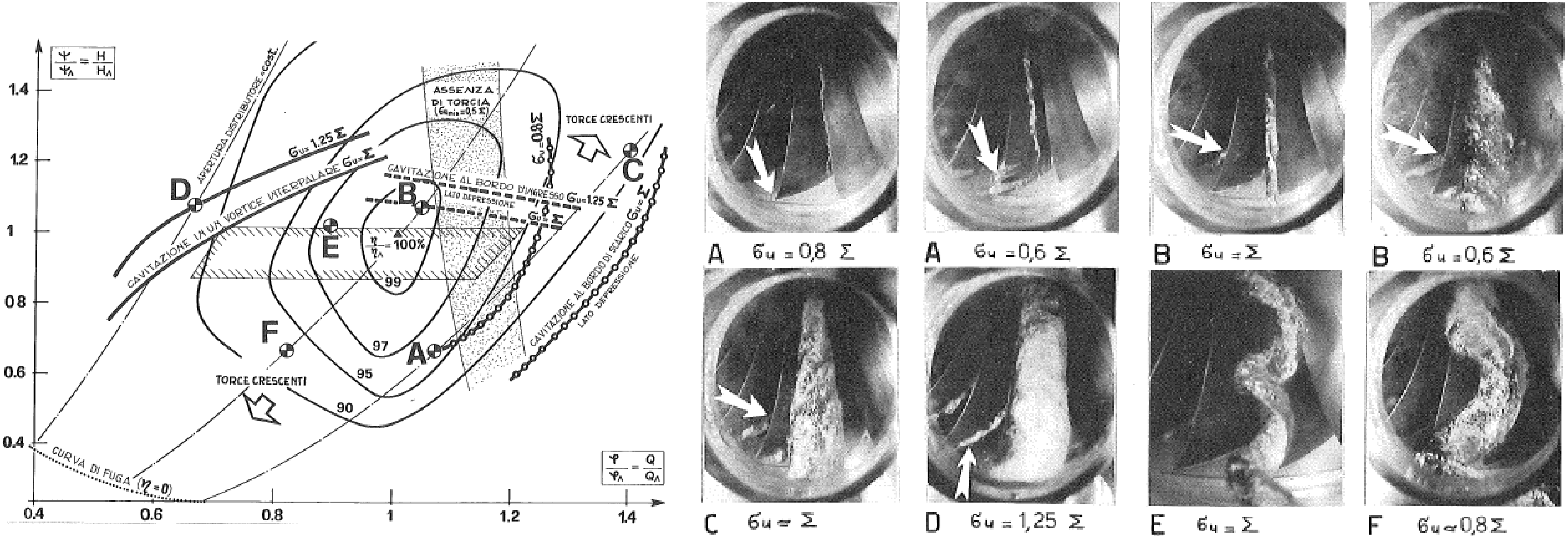


Fig. 14 Francis veloci: diagramma collinare dei rendimenti con cavitazioni e torce.

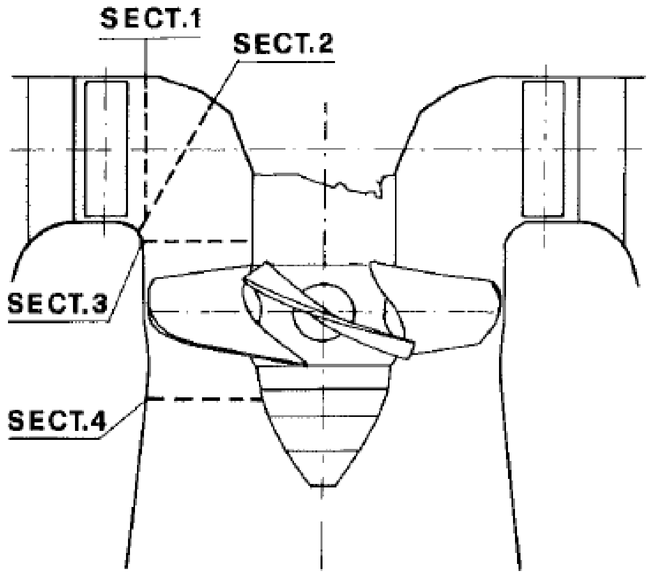


Figure 2 – Section méridienne du modèle Kaplan et position des sections de mesure

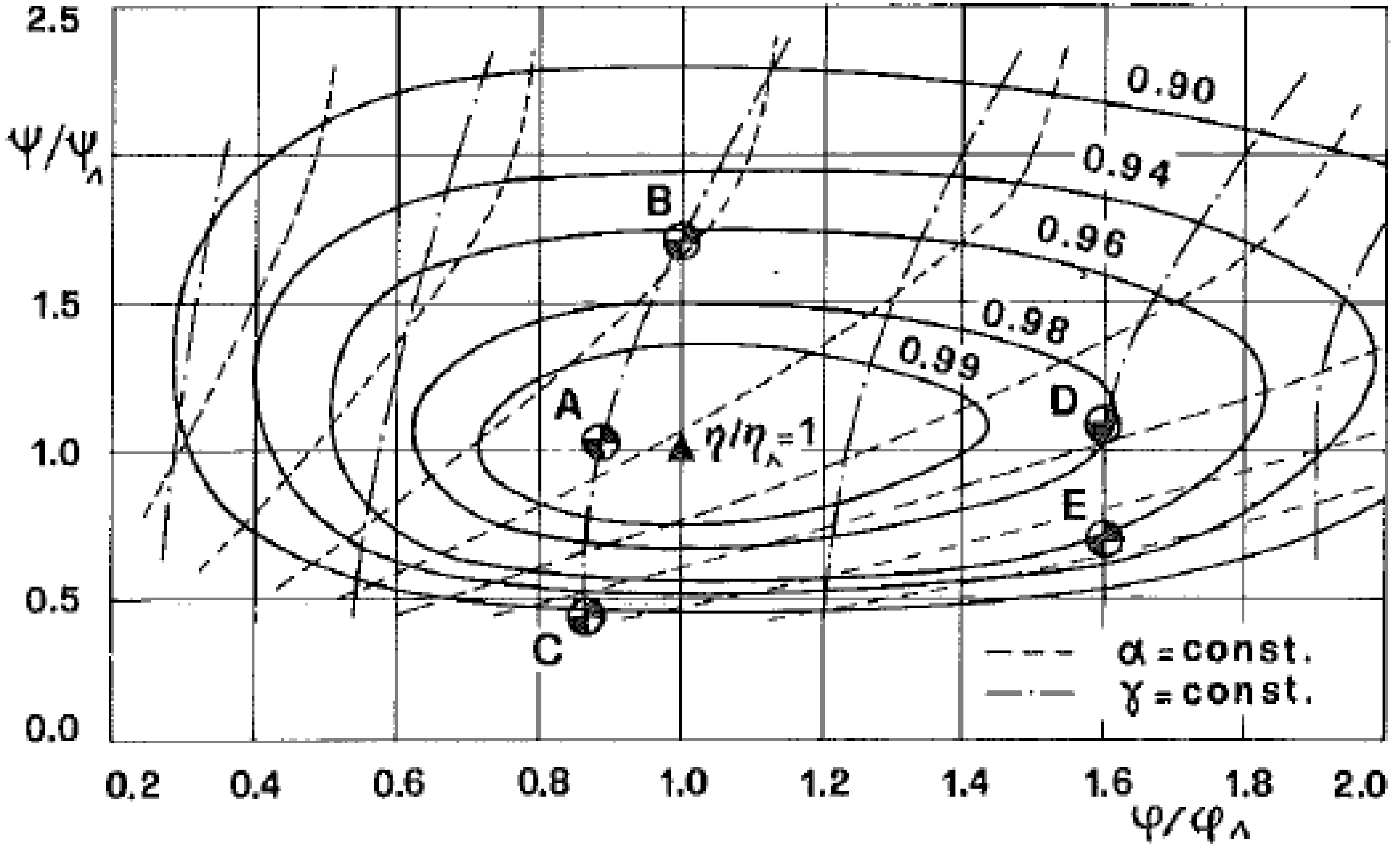


Figure 1 – Diagramme en colline des rendements du modèle Kaplan.

$$C_p = \frac{p-(p_a - h_s\,\rho\, g)}{(\rho\, u_e^2/2)}$$

Quand la pression p sur les aubes atteint la tension de vapeur p_v, on a :

$$C_p = \frac{p_v-(p_a - h_s\,\rho\, g)}{\rho\, u_e^2/2} = -\frac{\mathrm{NPSH}}{u_e^2/2g} = -\sigma_u$$

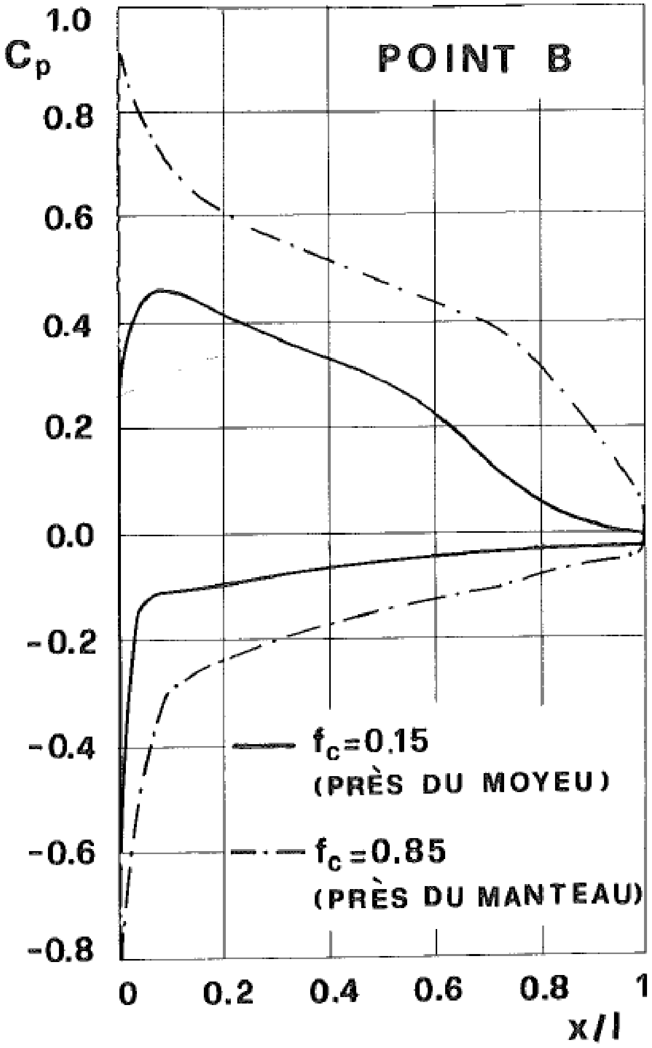
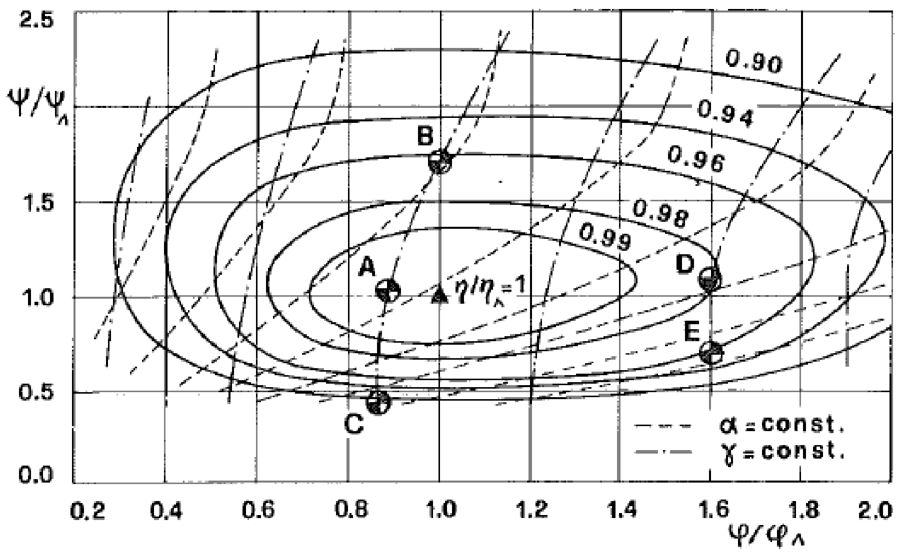
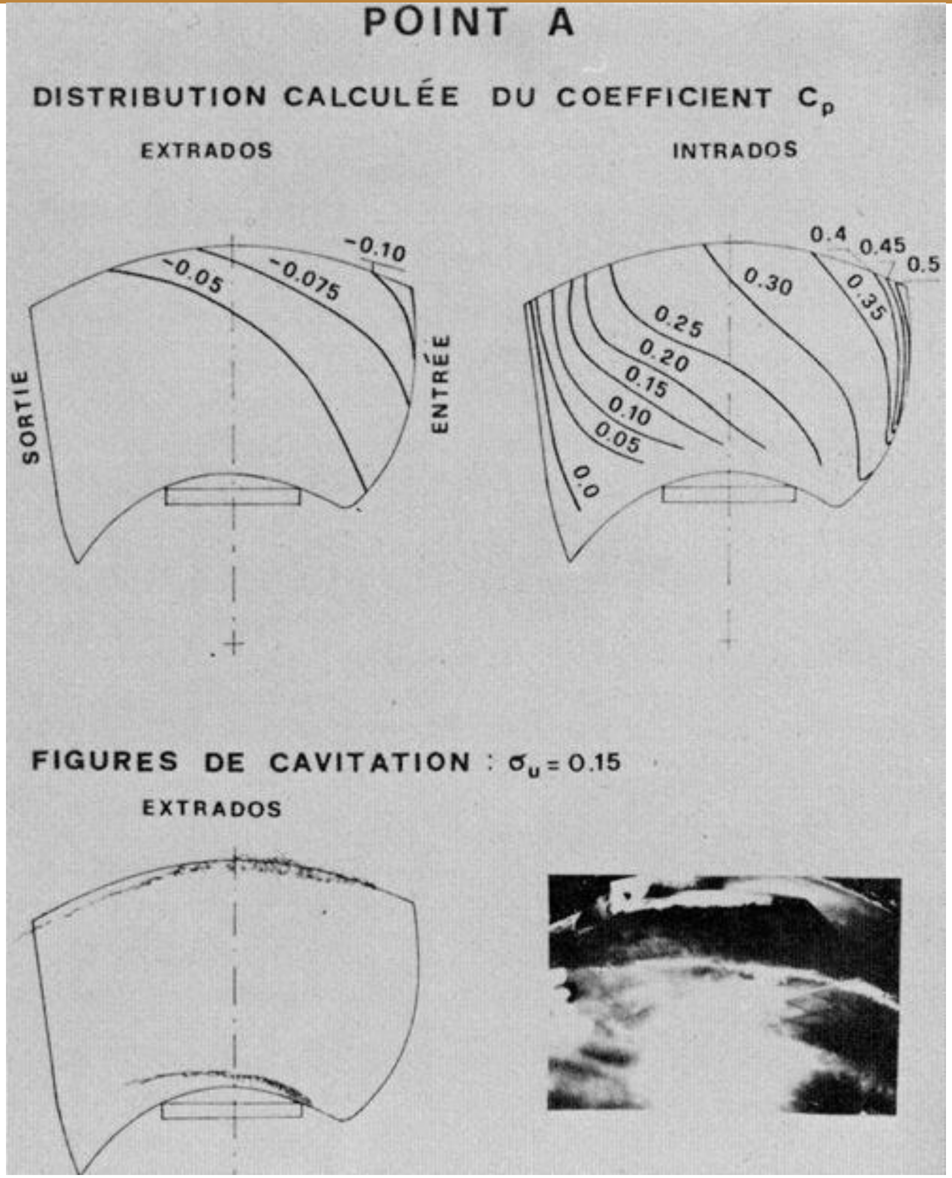


Figure 12 – Répartitions des pressions sur les profils des aubes pour deux surfaces axialsymétriques.





POINT A

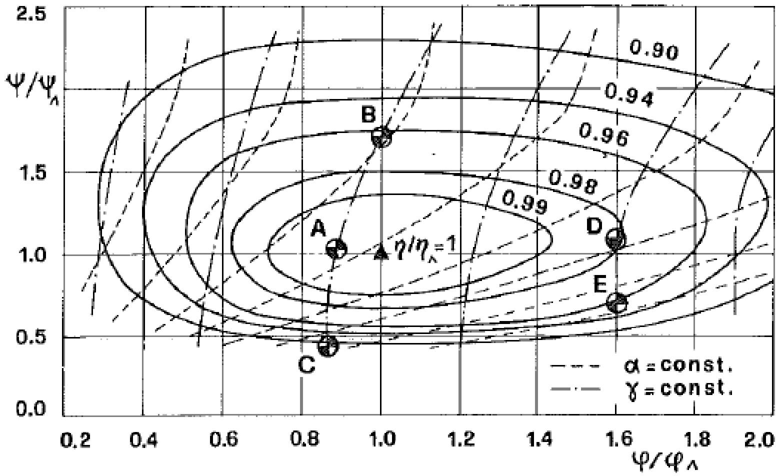
DISTRIBUTION CALCULÉE DU COEFFICIENT C_p

EXTRADOS

INTRADOS

FIGURES DE CAVITATION : $\sigma_u = 0.15$

EXTRADOS



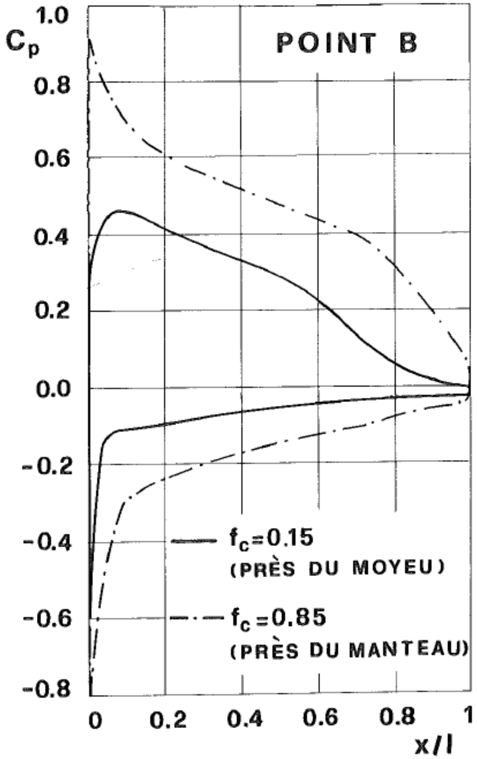
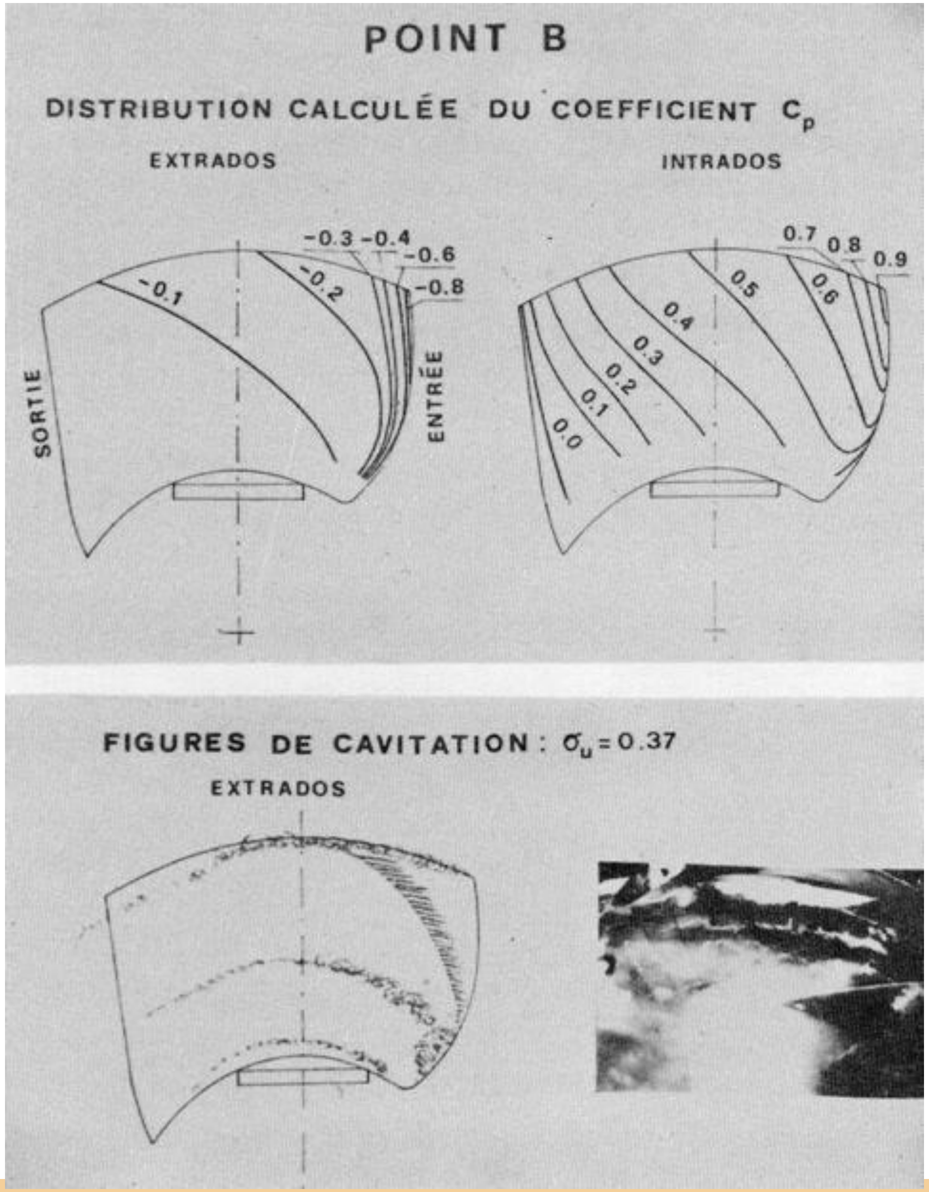
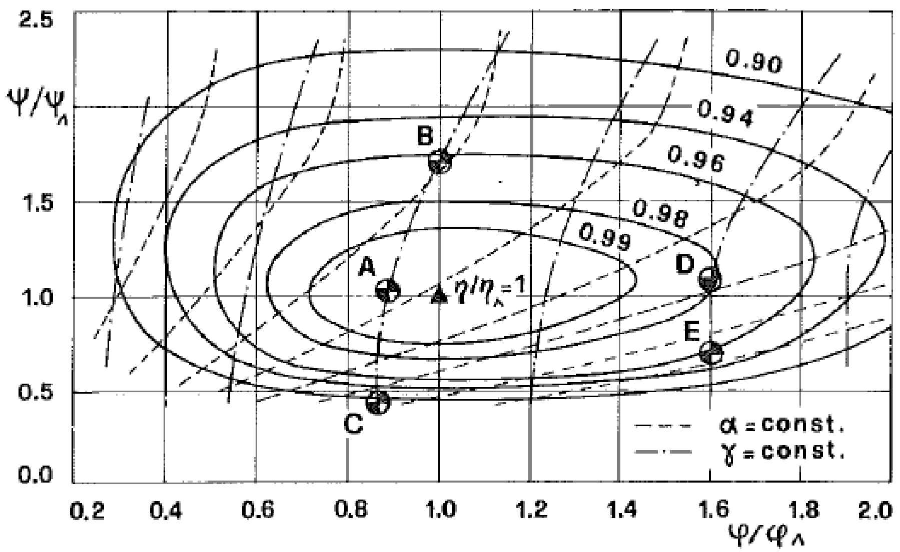
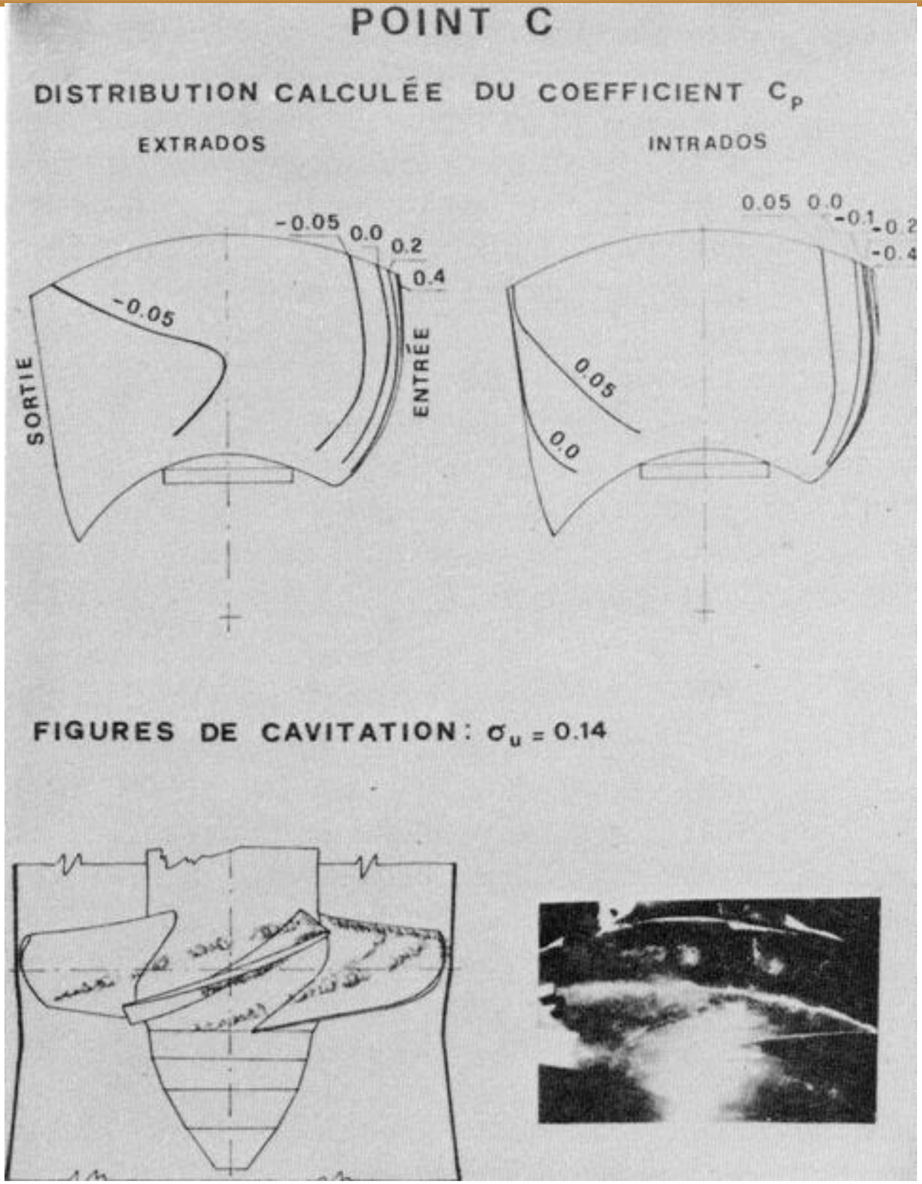


Figure 12 – Répartitions des pressions sur les profils des aubes pour deux surfaces axialsymétriques.



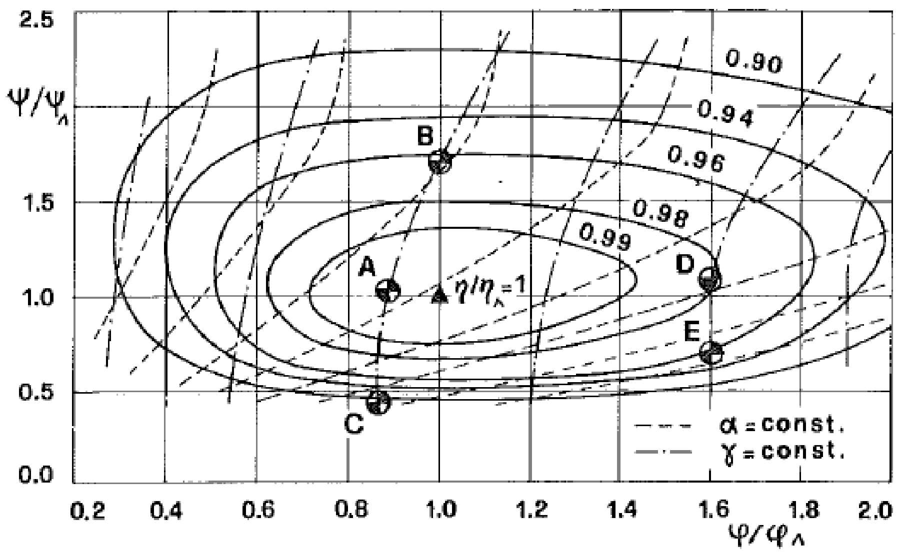




POINT C

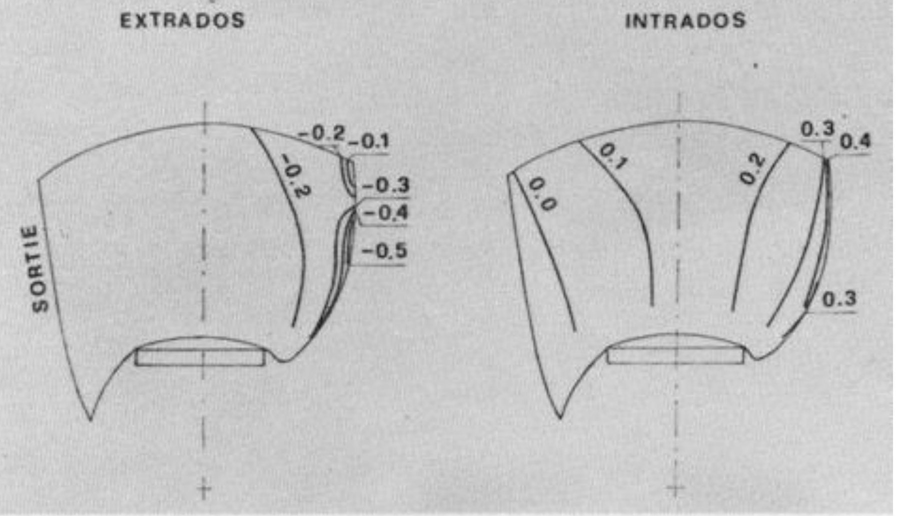
DISTRIBUTION CALCULÉE DU COEFFICIENT C_p

FIGURES DE CAVITATION : $\sigma_u = 0.14$

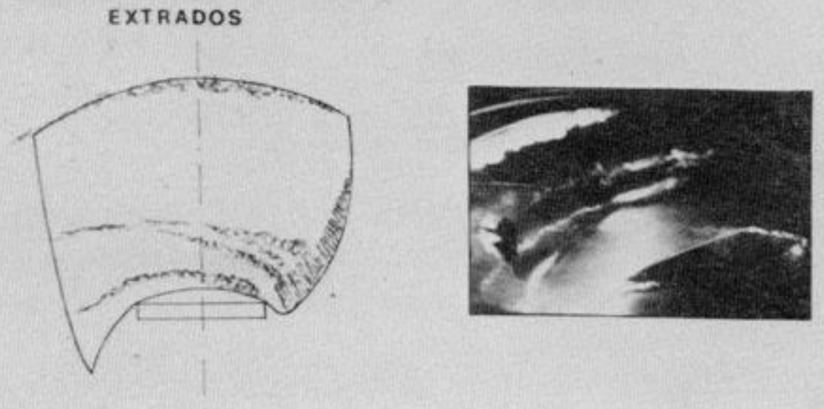


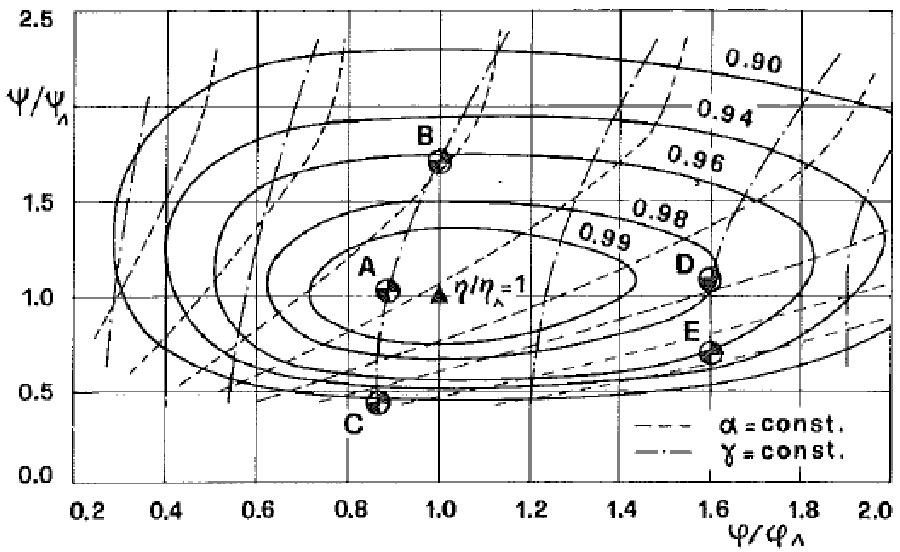
POINT D

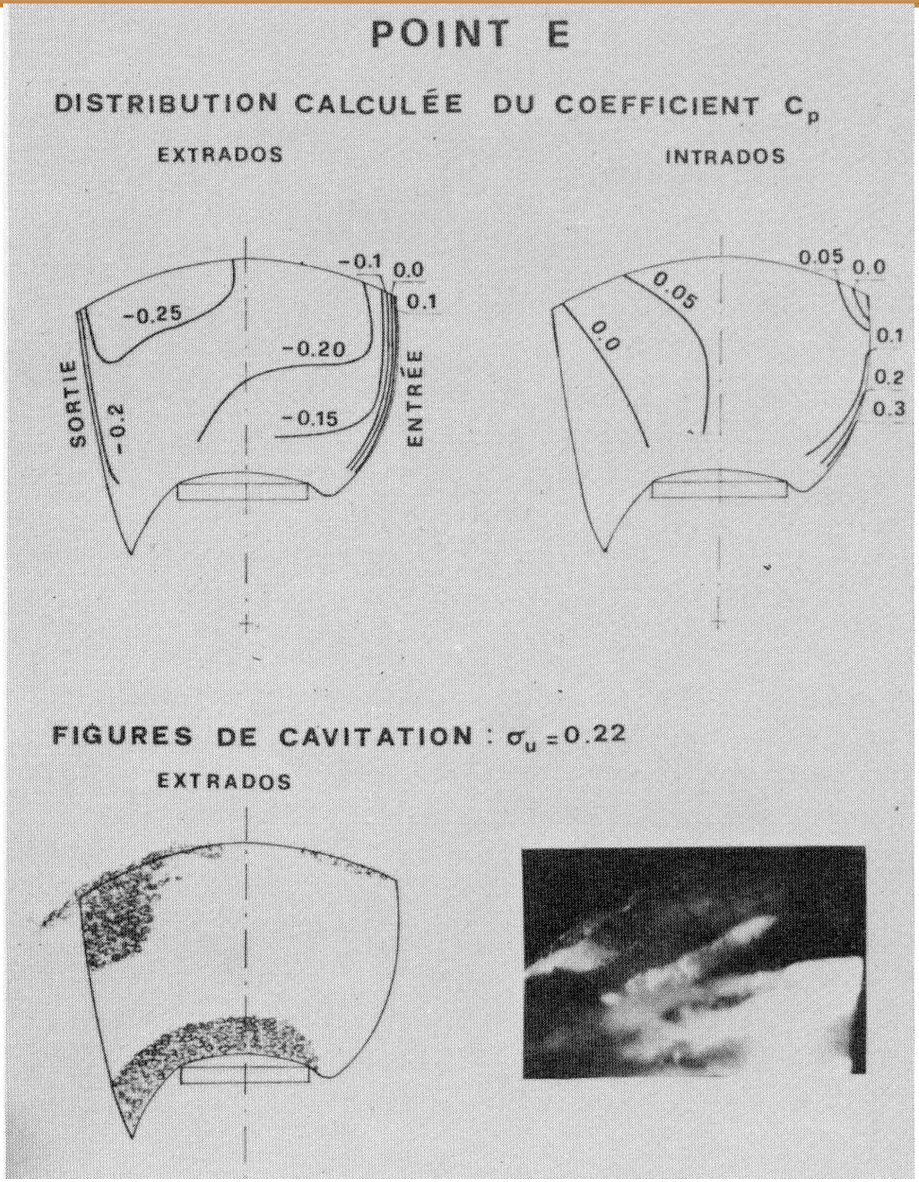
DISTRIBUTION CALCULÉE DU COEFFICIENT C_p



FIGURES DE CAVITATION : $\sigma_u = 0.29$







POINT E

DISTRIBUTION CALCULÉE DU COEFFICIENT C_p

FIGURES DE CAVITATION : $\sigma_u = 0.22$

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