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UNIVERSITÉ DE LIÈGE
FACULTÉ DES SCIENCES APPLIQUÉES

COURS DE MACHINES HYDRAULIQUES

professé par Albert SCHLAG

RECUEIL DE FIGURES

extraites, avec l'autorisation de l'auteur, du traité

LES MACHINES ROTATIVES, par le Professeur Ch. HANOCQ

1955

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TURBINES

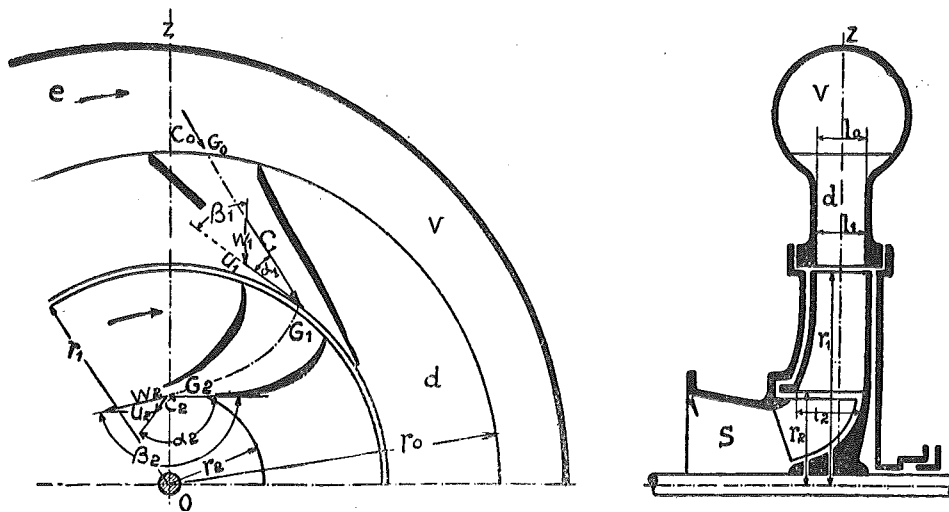


FIG. 1.

$$m = \frac{r_2}{r_1} \quad \varepsilon = \frac{l_1}{r_1} \quad v = \frac{l_2}{l_1} \quad n = \frac{1}{m} \cdot \frac{1}{v} \cdot \frac{\sin \alpha_1}{\sin \beta_2}$$

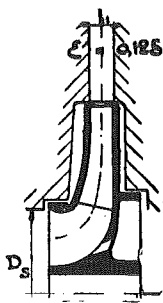


FIG. 2.

Turbine centrifète TFV
R = 0,02 à 0,125

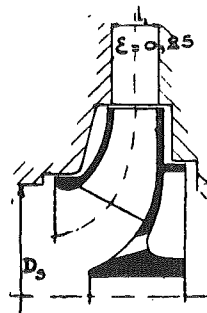


FIG. 3.

Turbine hélico-centrifète FV
R = 0,125 à 0,25

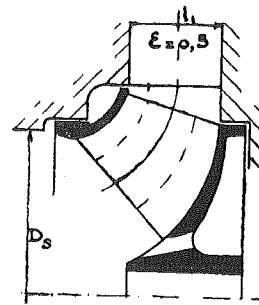


FIG. 4.

Turbine hélico-centrifète MV
R = 0,25 à 0,5

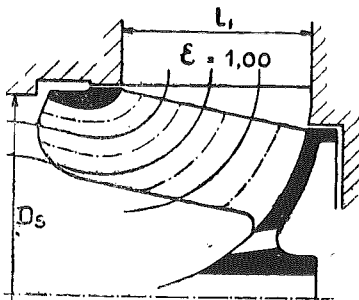


FIG. 5.

Turbine mixte GV
R = 0,5 à 1

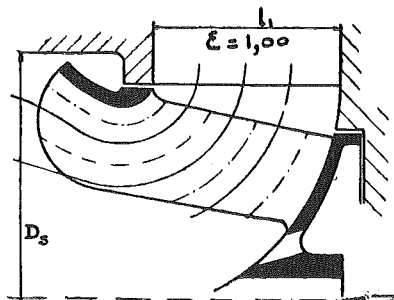


FIG. 6.

Turbine mixte TGV
R = 1 à 2

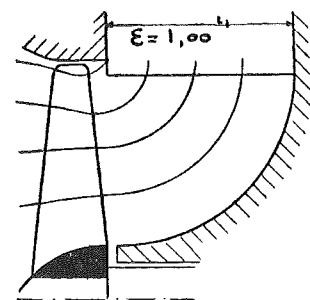


FIG. 7.

Turbine hélicoïde TTGV
R = 2 à 10

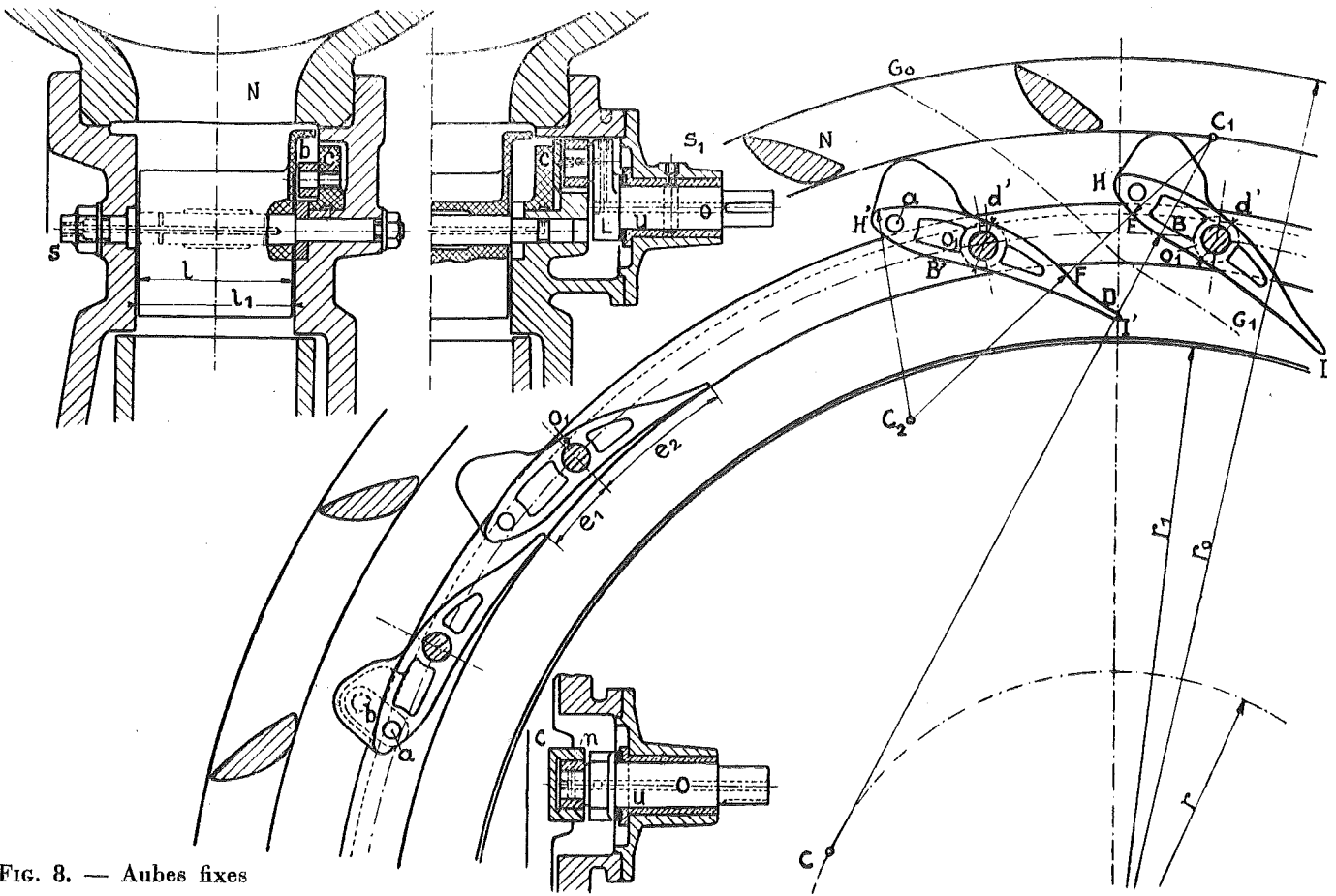


FIG. 8. — Aubes fixes

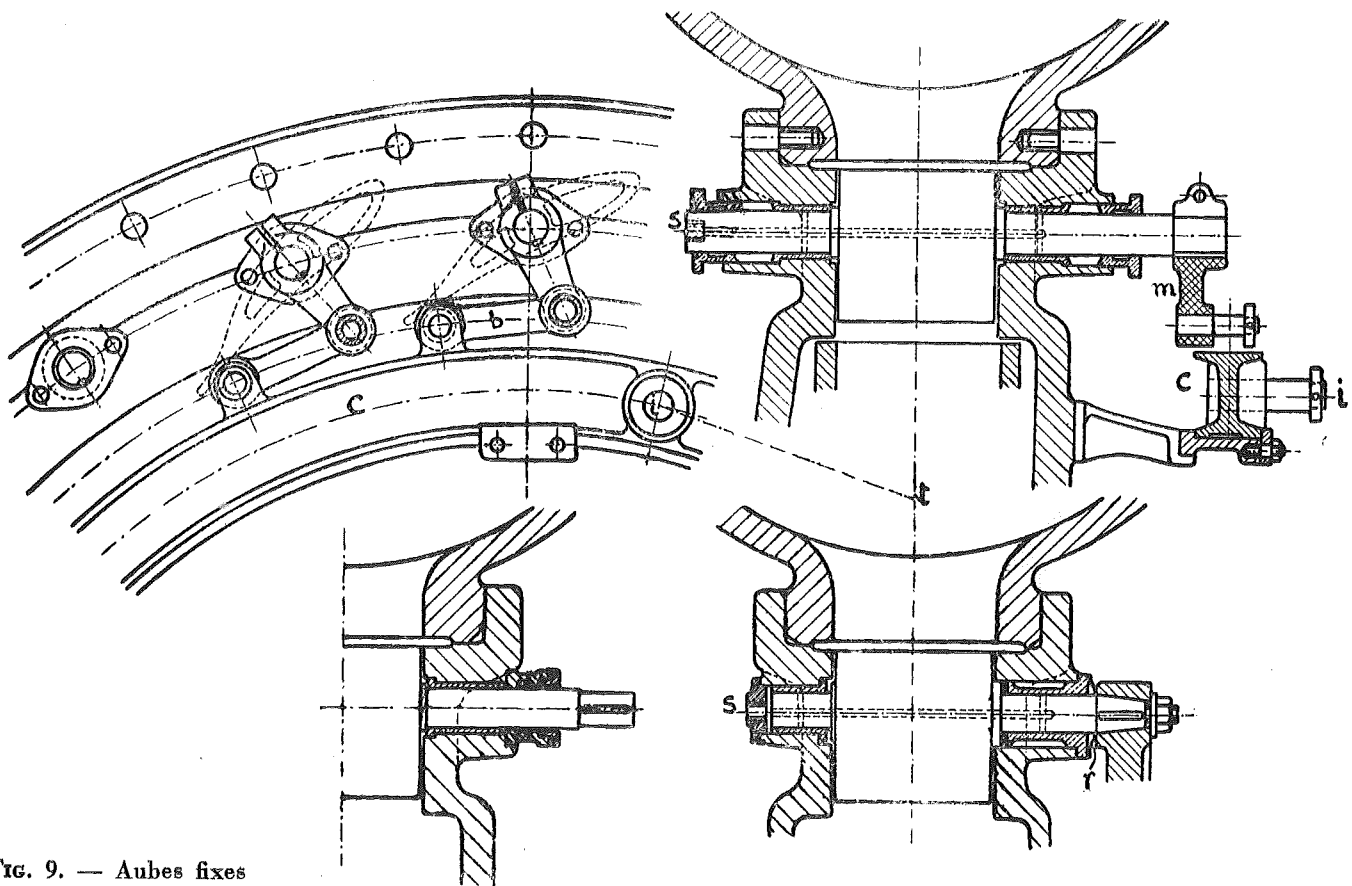


FIG. 9. — Aubes fixes

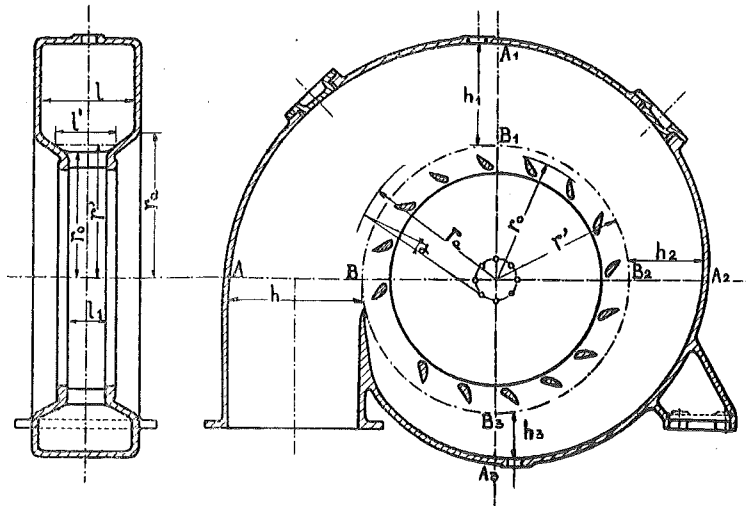


FIG. 10.

Volute à section rectangulaire

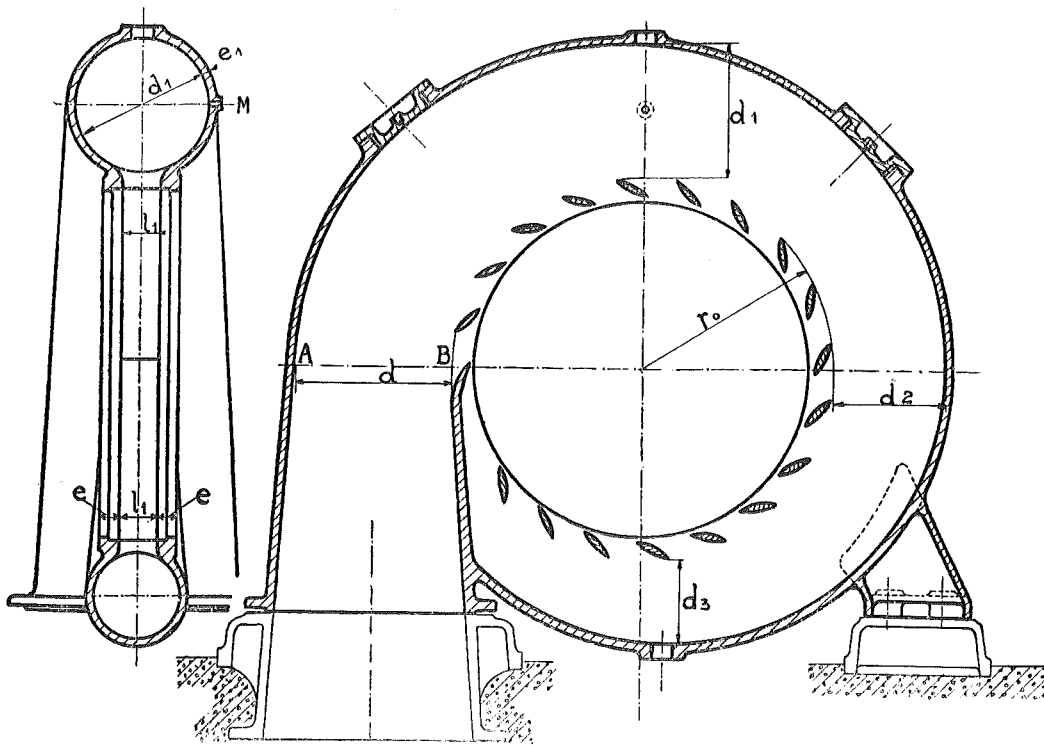


FIG. 11.

Volute à section circulaire

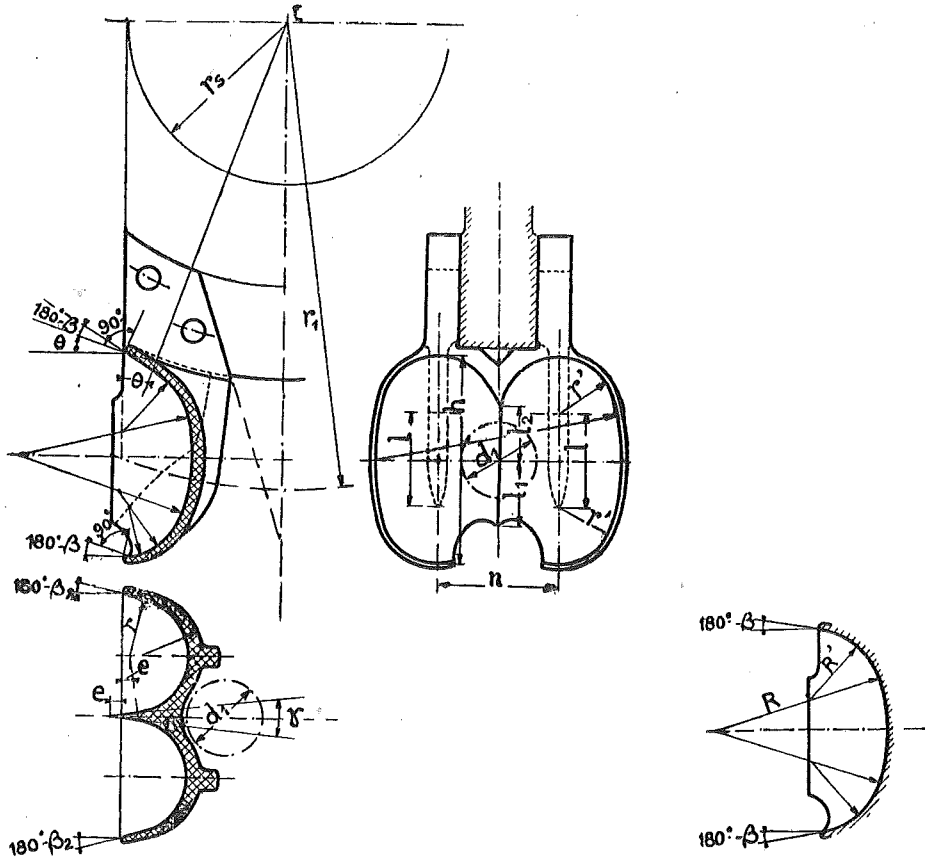


FIG. 12.

Turbine Pelton : auget

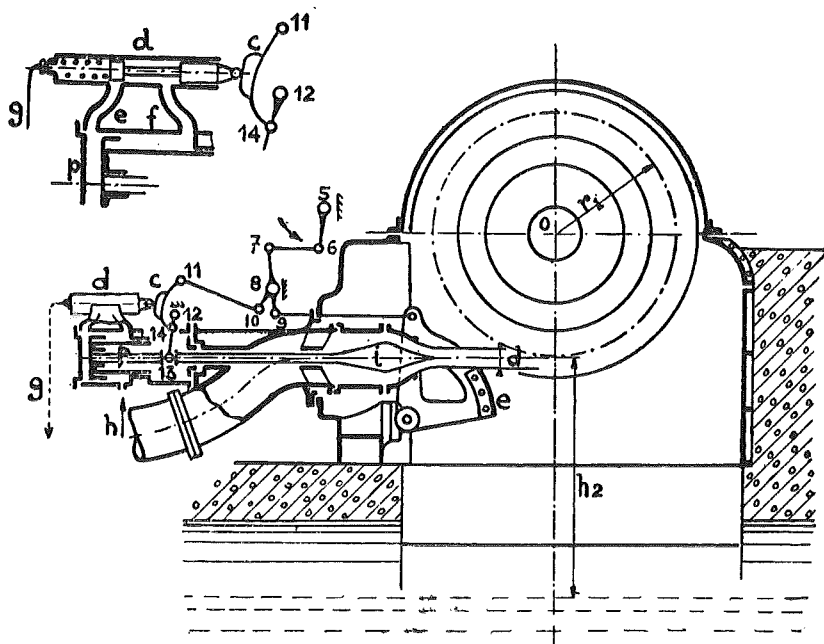


FIG. 16.

Turbine Pelton : régulateur et déflecteur

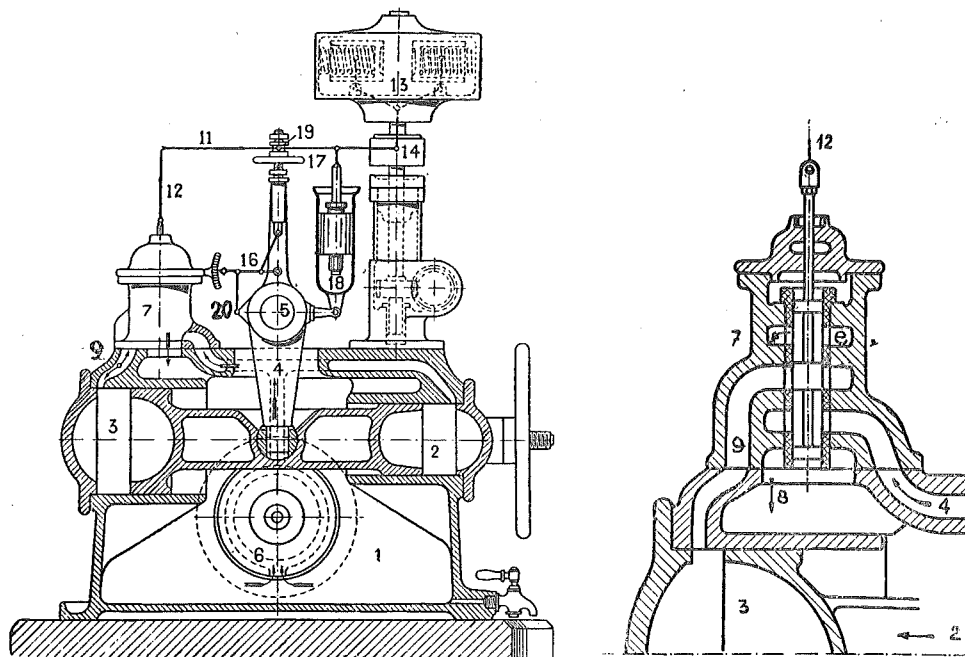


FIG. 13. — Régulateur à servo-moteur

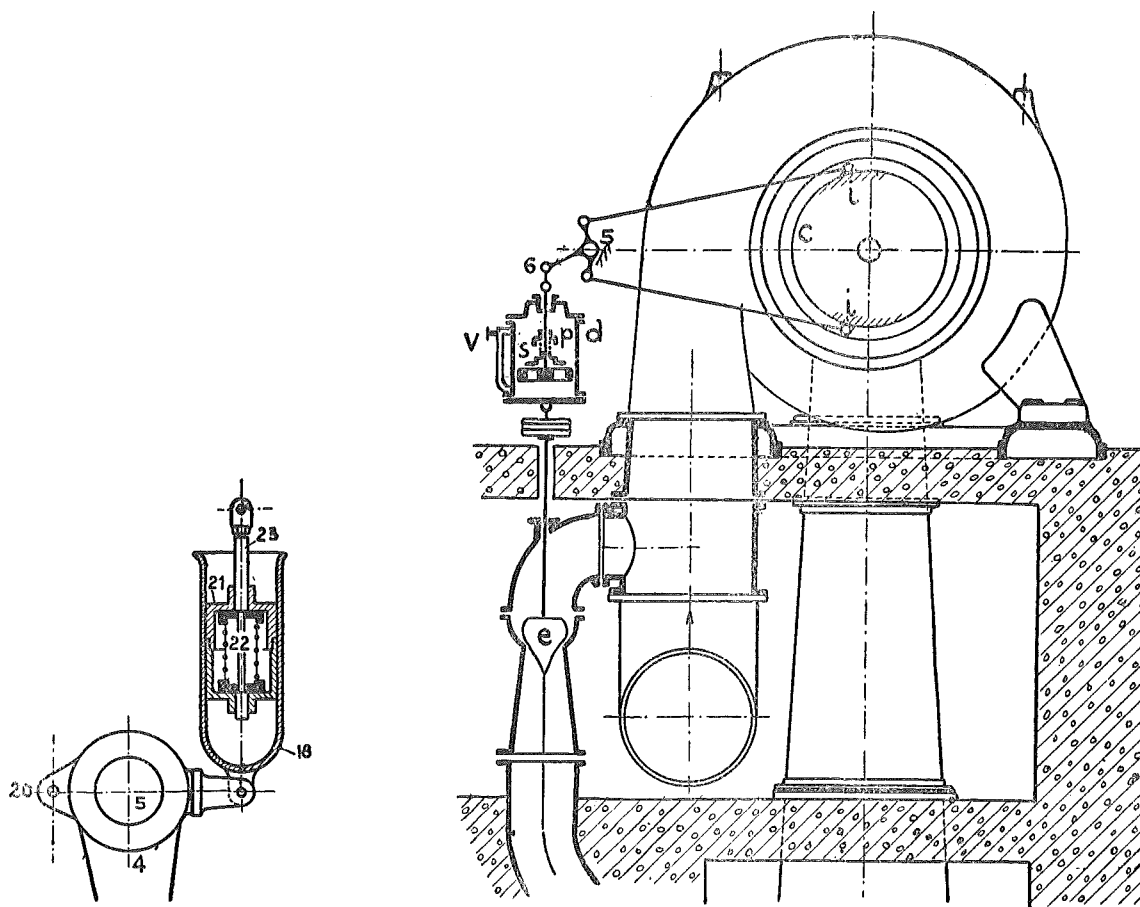


FIG. 14. — Régulateur : frein à huile

FIG. 15. — Commande du cercle de vannage

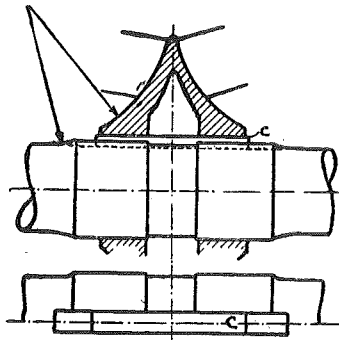


FIG. 17.

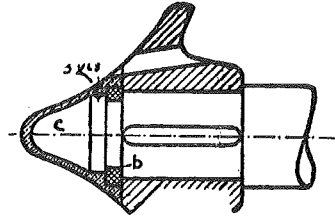


FIG. 18.

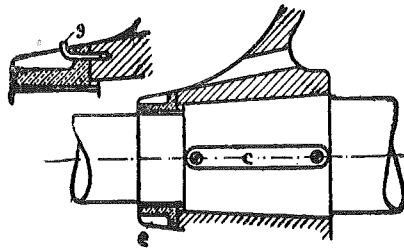


FIG. 19.

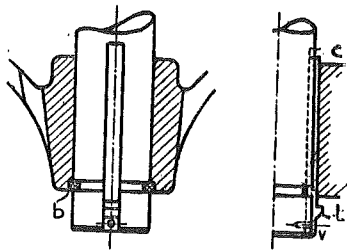


FIG. 20.

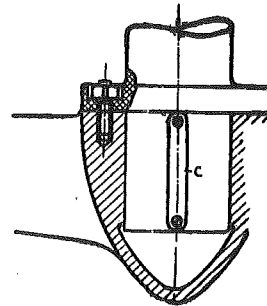


FIG. 21.

Calage de la roue sur l'arbre

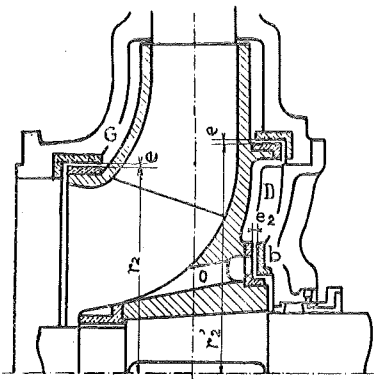


FIG. 22.

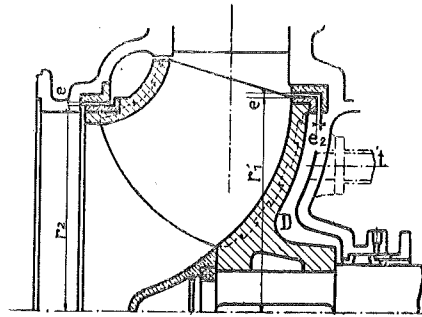


FIG. 23.

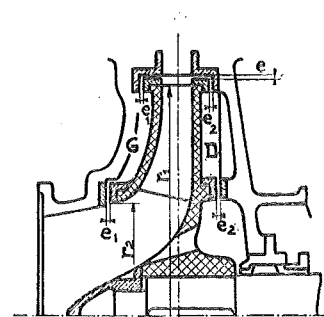


FIG. 24.

Dispositifs d'étanchéité

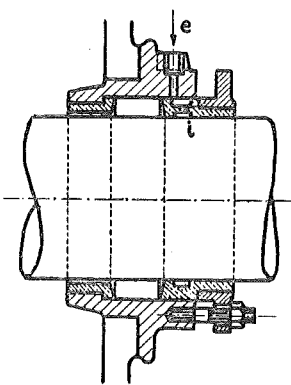


FIG. 25.

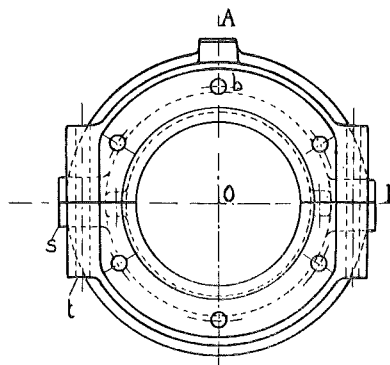


FIG. 26.

Coupe AOB

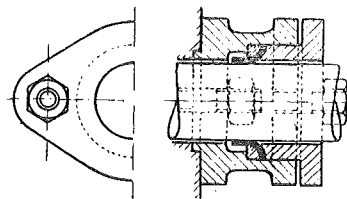
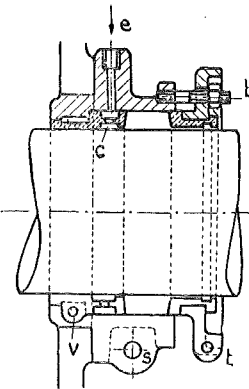


FIG. 27.

Boîtes à bourrage

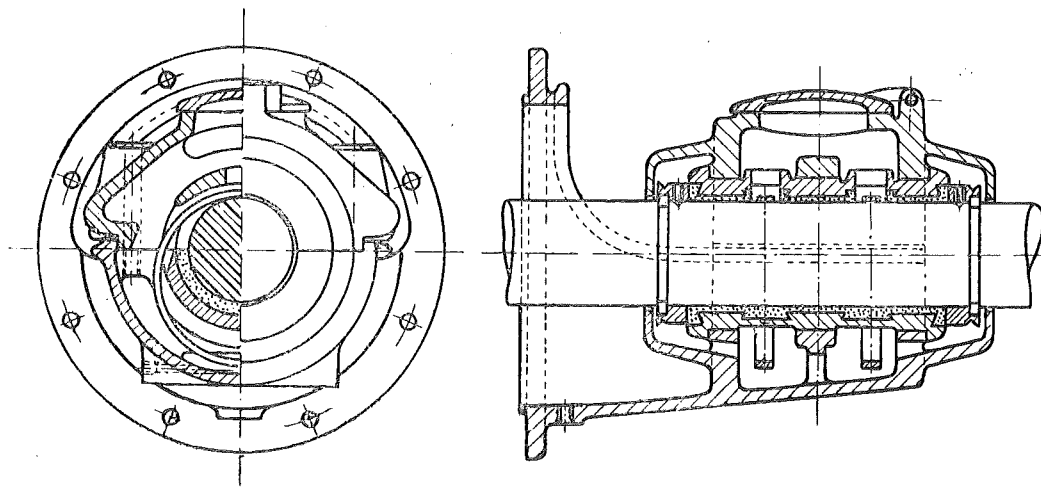


FIG. 28. — Palier

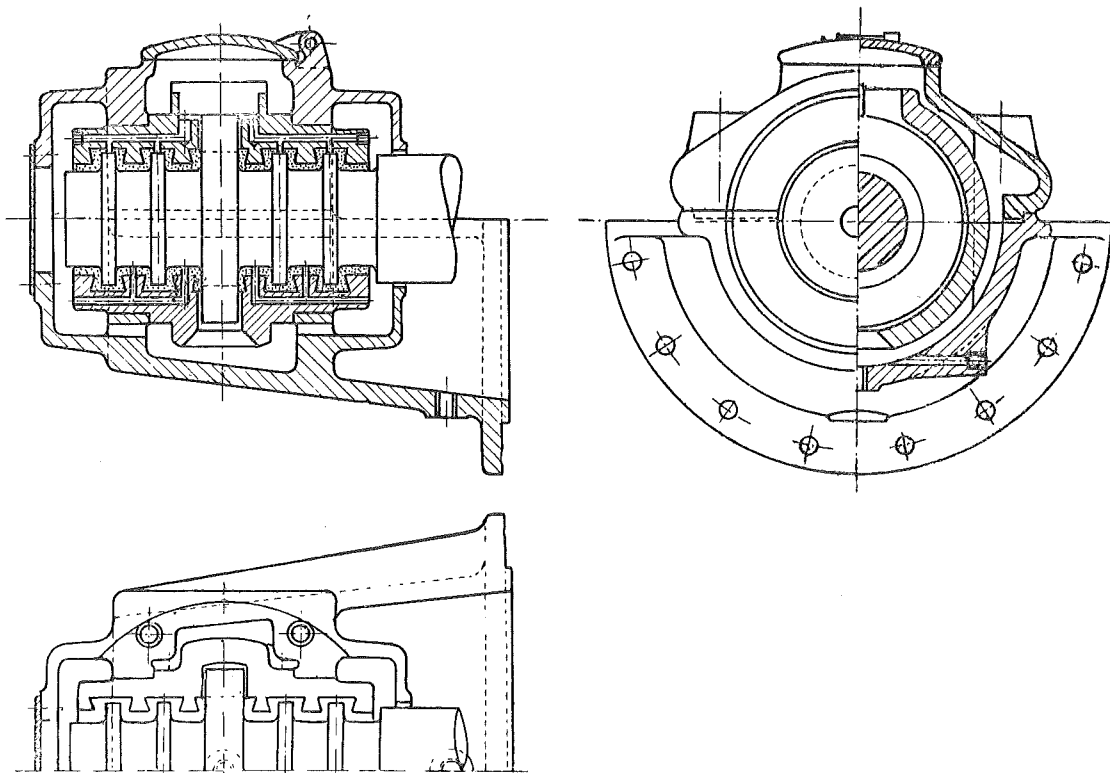


FIG. 29. — Palier

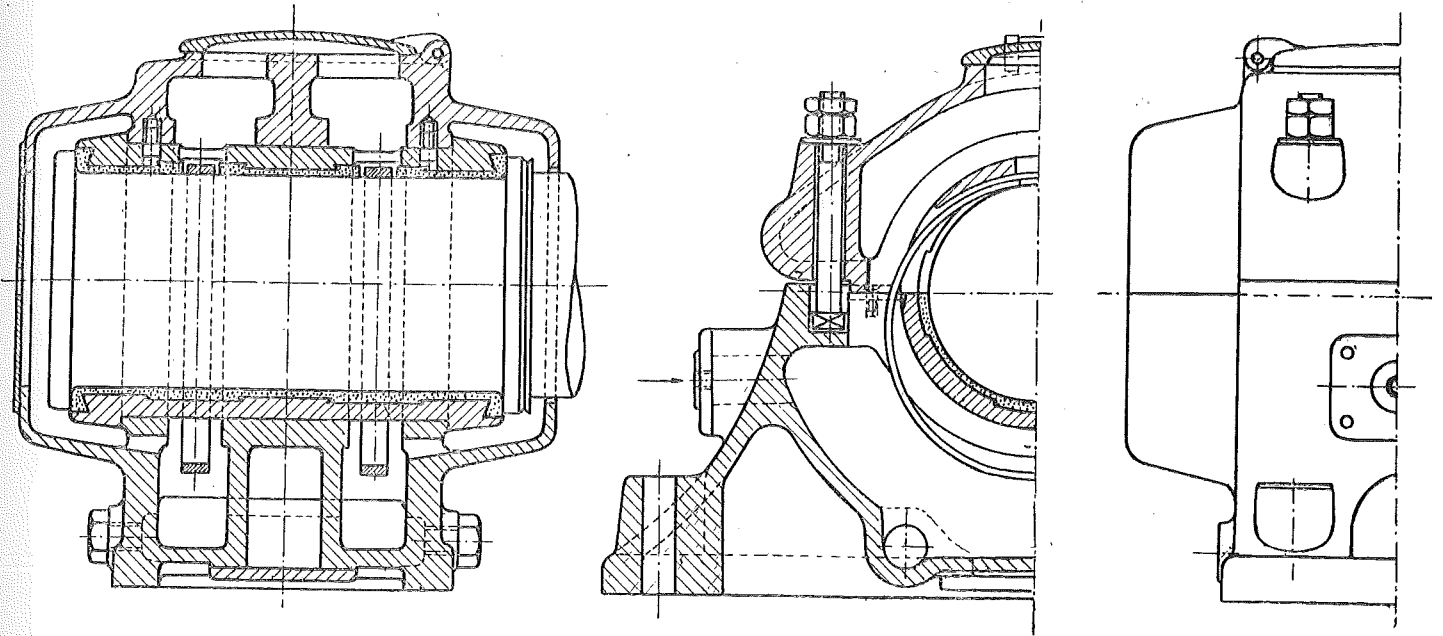


FIG. 30. — Palier

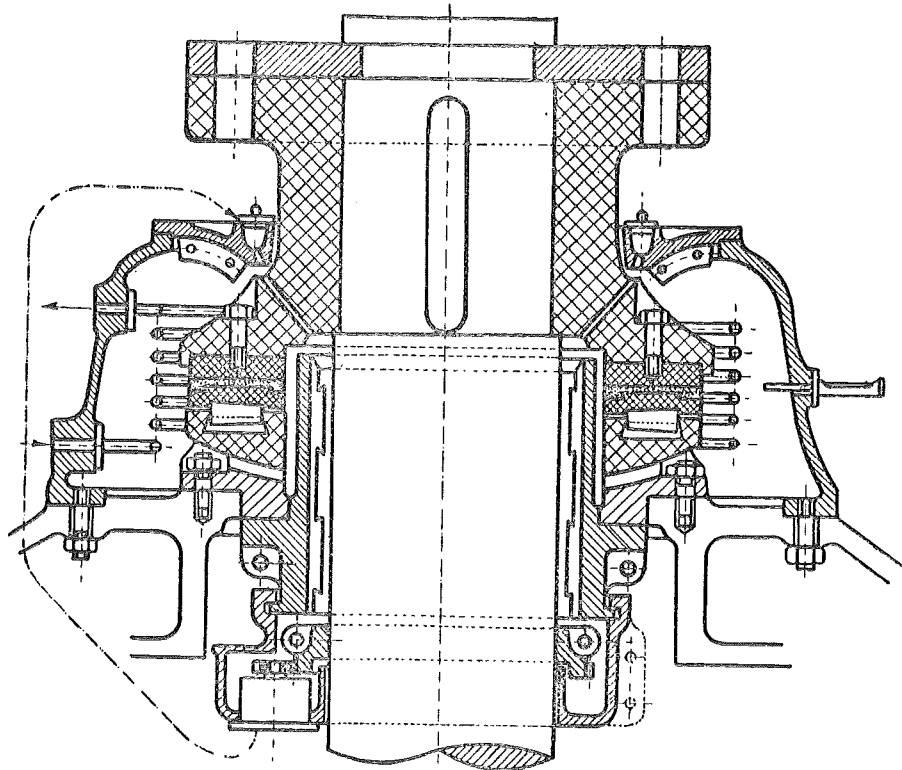


FIG. 31. — Butée

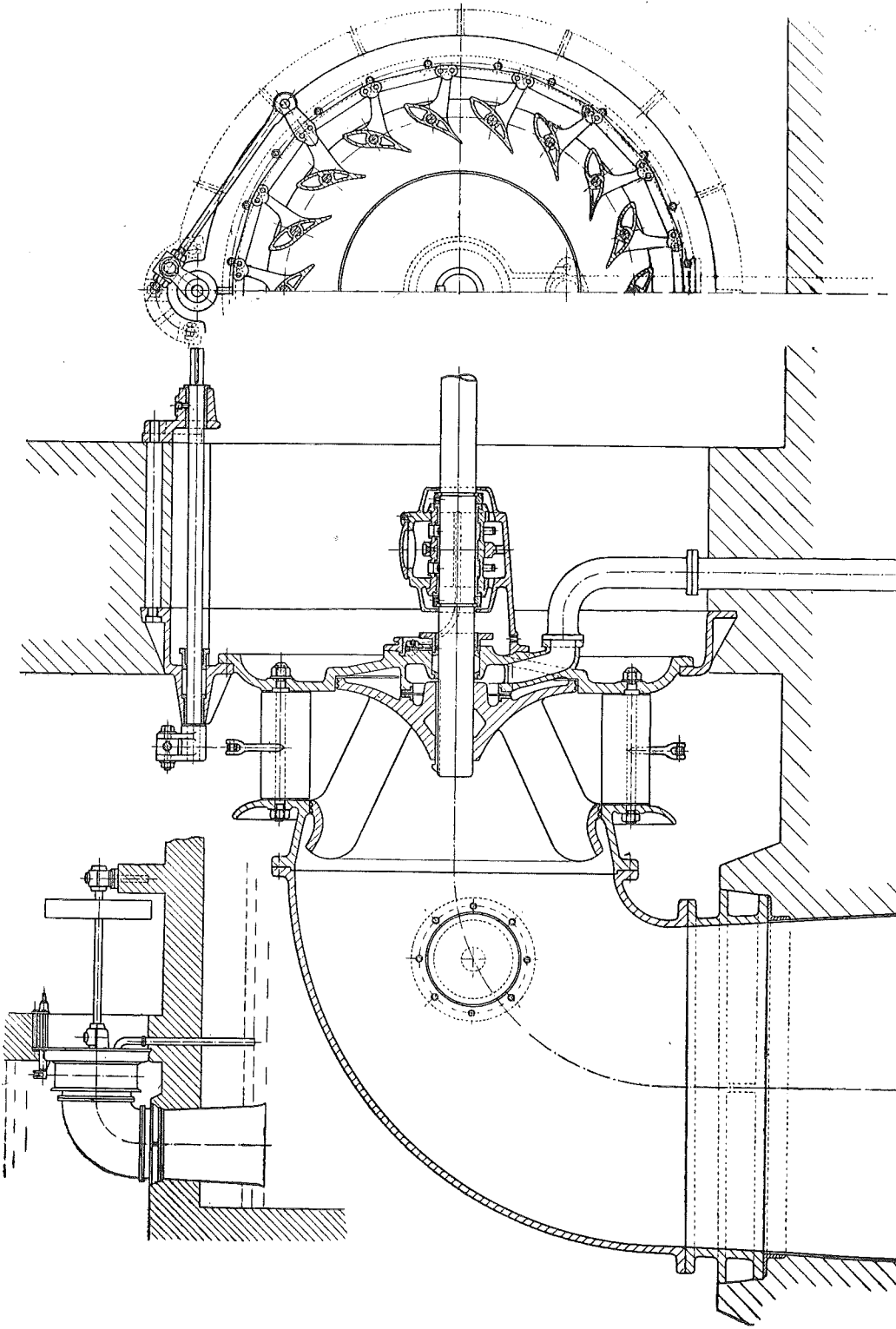


FIG. 32.

$N_e = 140$ ch. $Q = 3$ m³/sec $H' = 4,50$ $N = 250$ $R = 2,5$ Echelles : 1/25 et 1/125

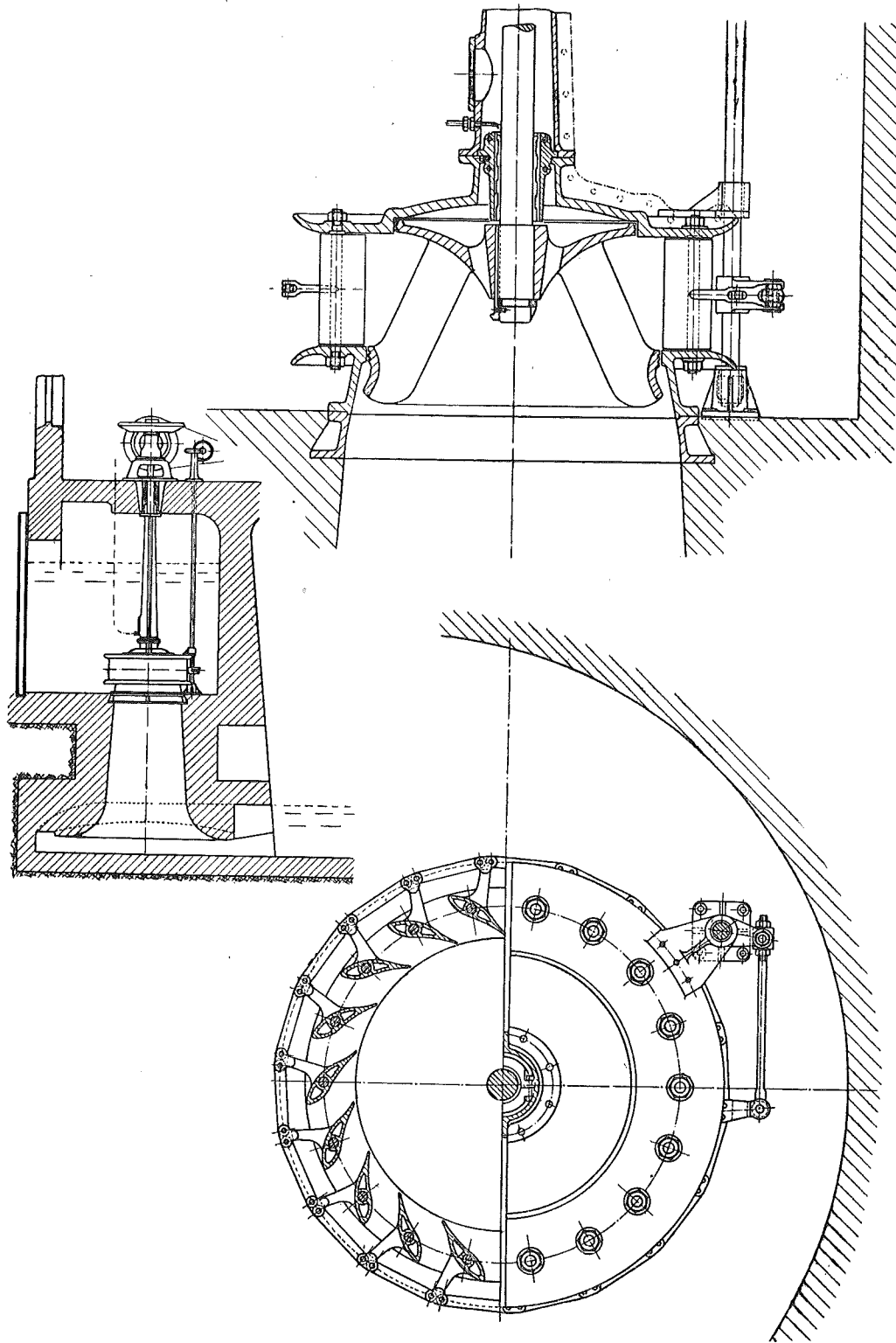


FIG. 33.

$N_e = 140$ ch. $Q = 3$ m³/sec $H' = 4,50$ $N = 250$ $R = 2,5$ Echelles : 1/25 et 1/125

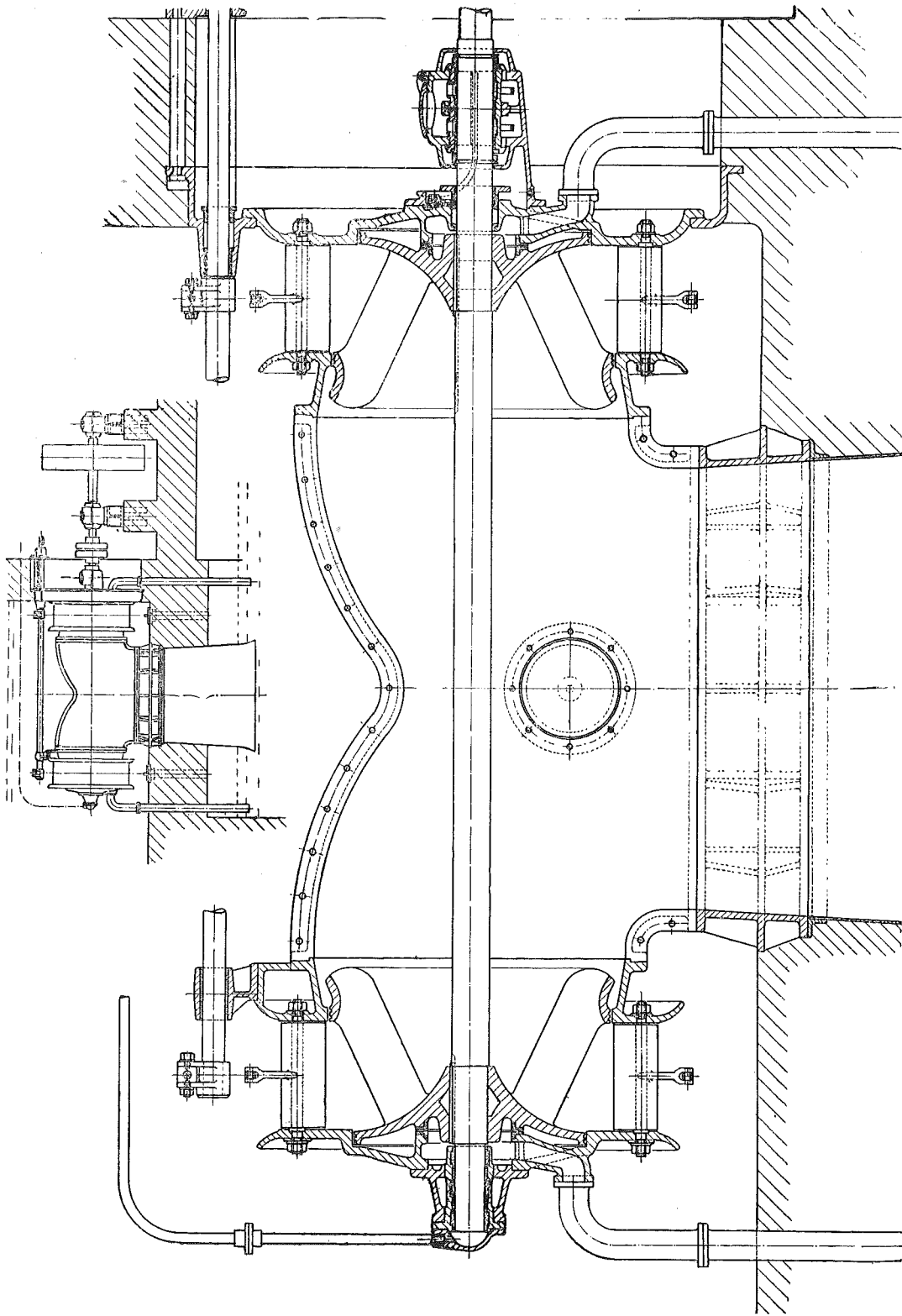


FIG. 34.

$N_e = 280$ ch. $Q = 6$ m³/sec $H' = 4.5$ $N = 250$ $R = 5$ Echelles : 1/25 et 1/125

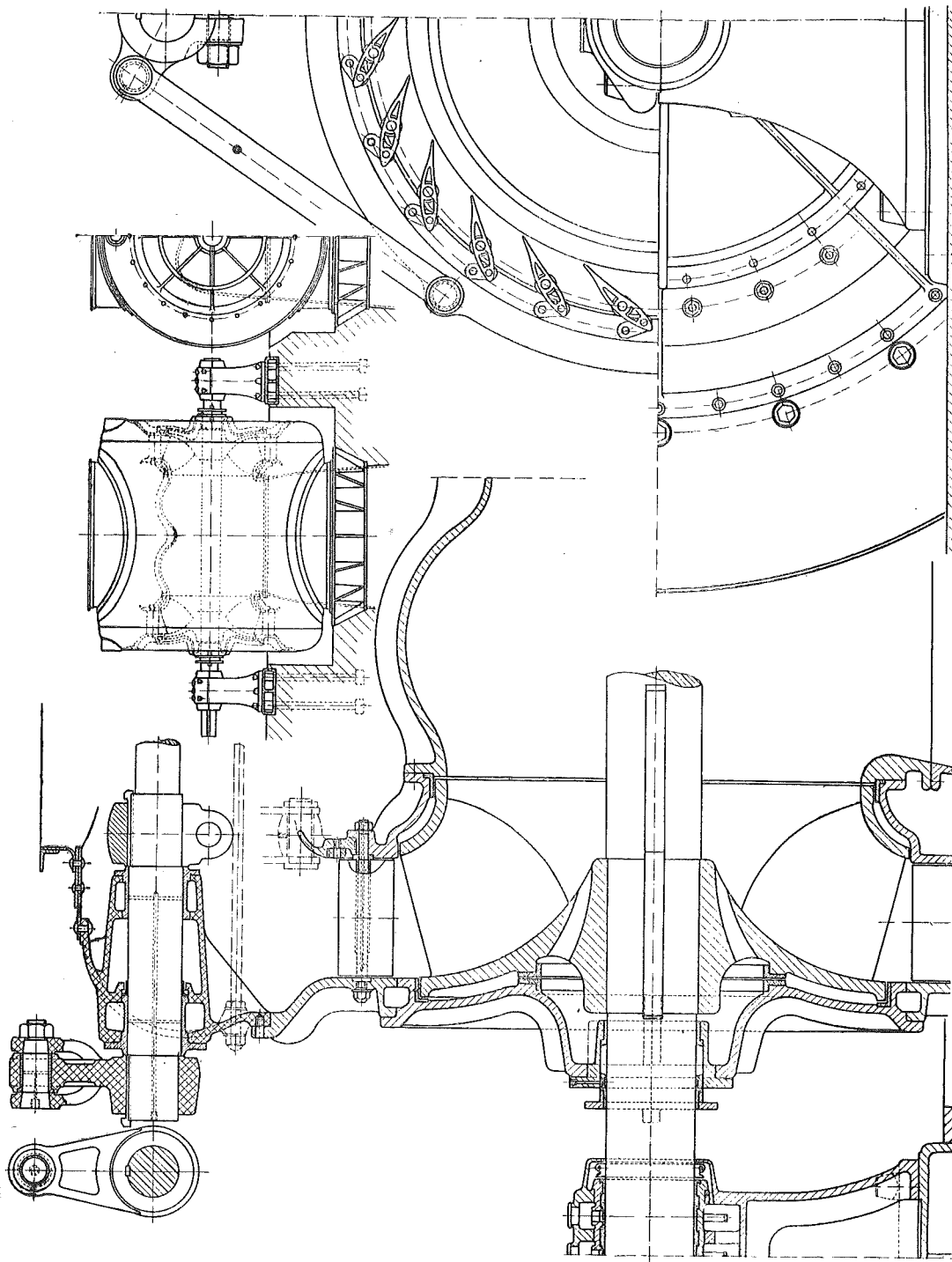


FIG. 35.

$N_e = 3500$ ch. $Q = 18$ m³/sec $H' = 17,5$ $N = 150$ $R = 0,8$ Echelles : 1/25 et 1/125

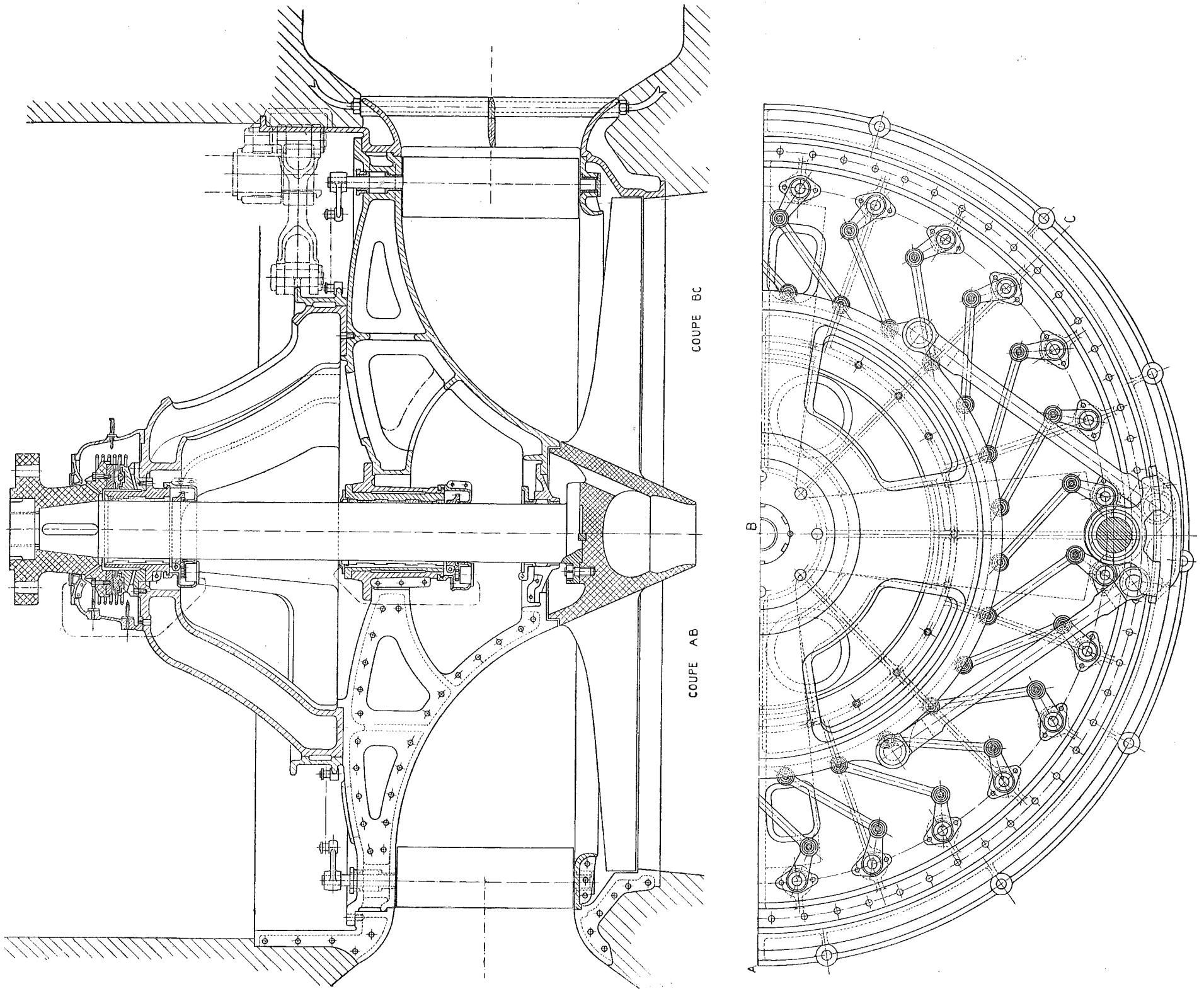


FIG. 37. — $N_e = 3500$ $Q = 36 \text{ m}^3/\text{sec}$ $H' = 9$ $N = 150$ $R = 3,85$ Echelle : 1/25

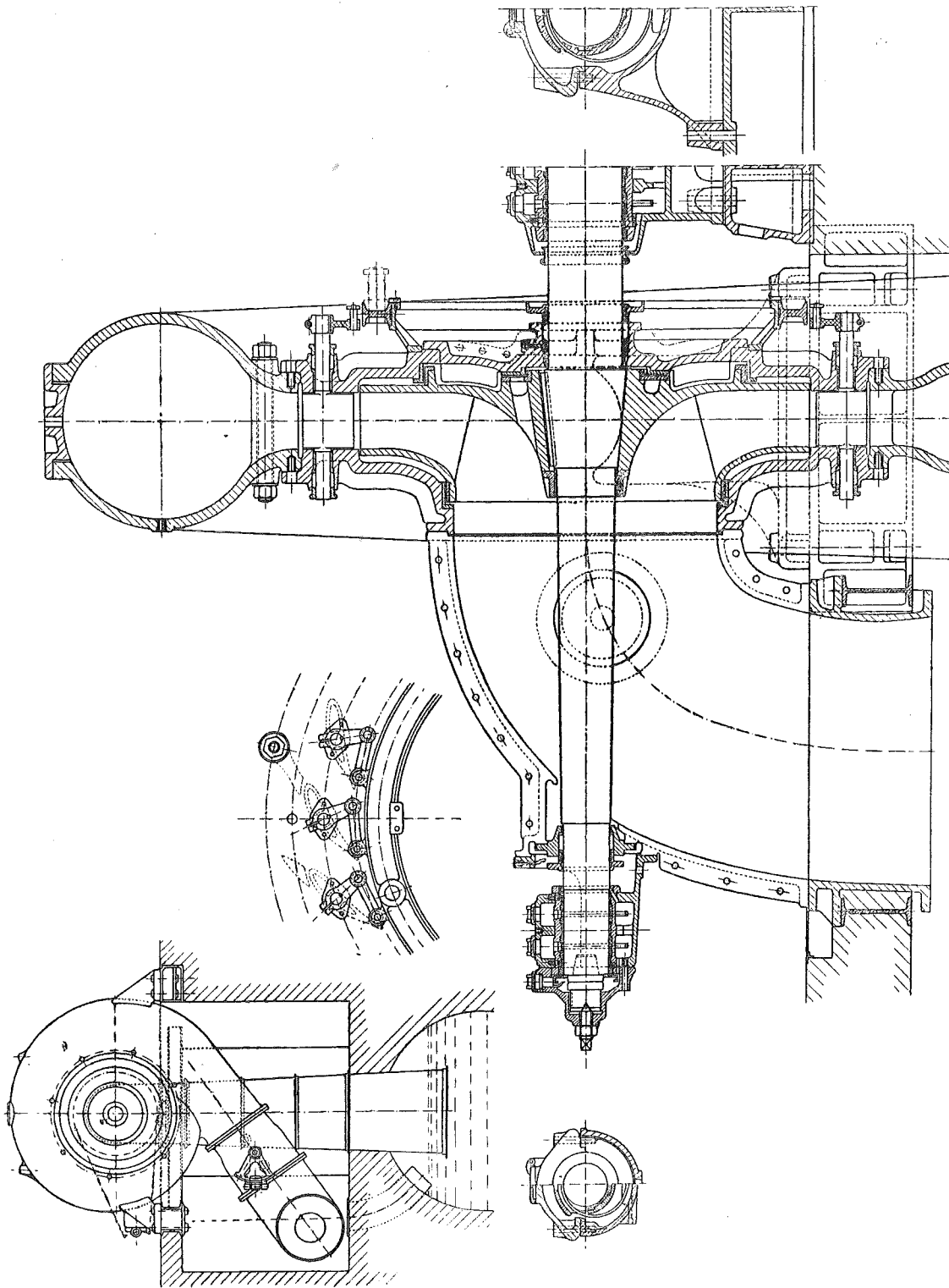


Fig. 38.
 $N_e = 3500$ $Q = 6 \text{ m}^3/\text{sec}$ $H' = 50$ $N = 250$ $R = 0,15$ Echelles : 1/25 et 1/125

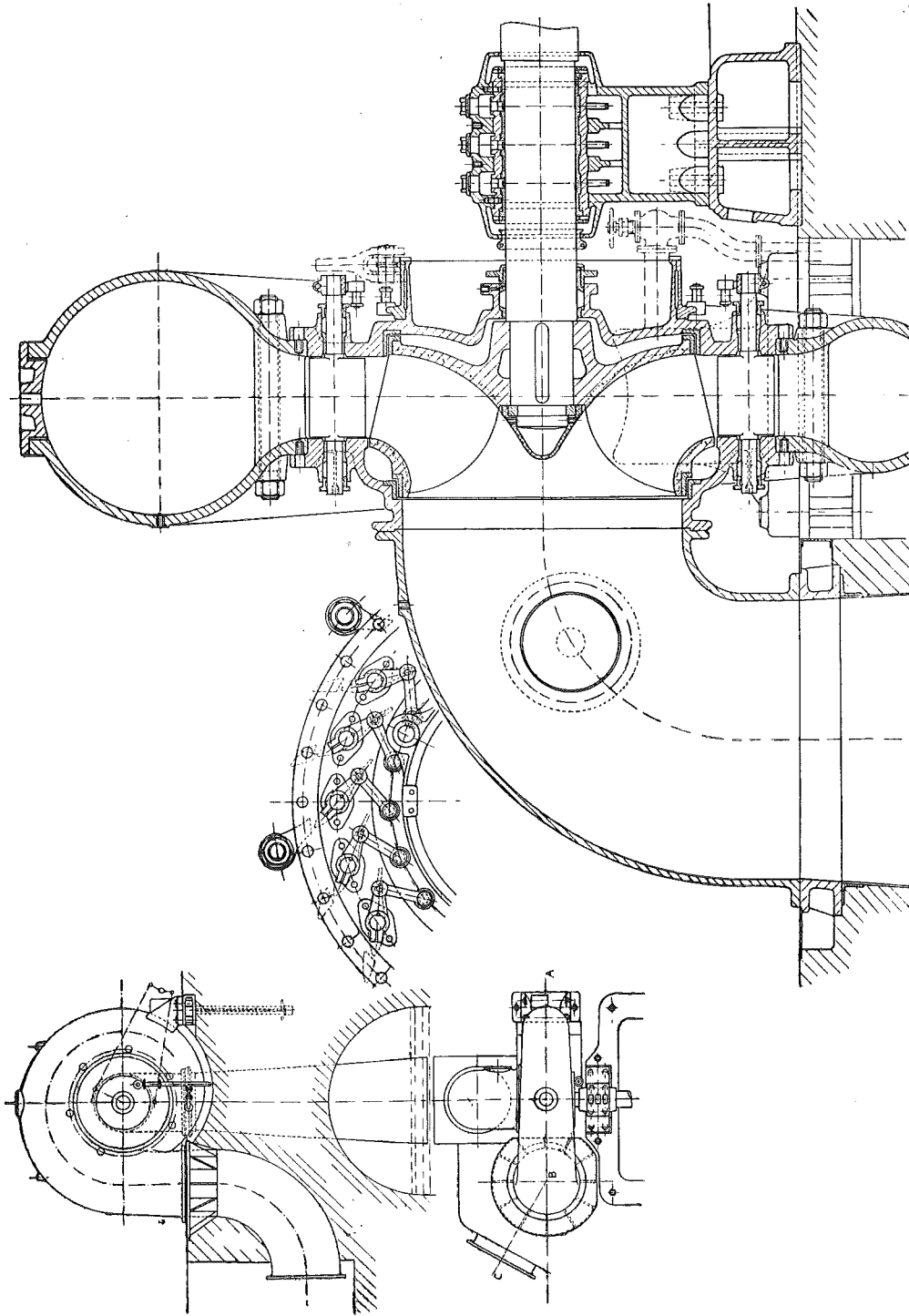


Fig. 39.

$N_e = 3500$ $Q = 6 \text{ m}^3/\text{sec}$ $H' = 50$ $N = 375$ $R = 0,35$ Echelles : $1/25$ et $1/125$

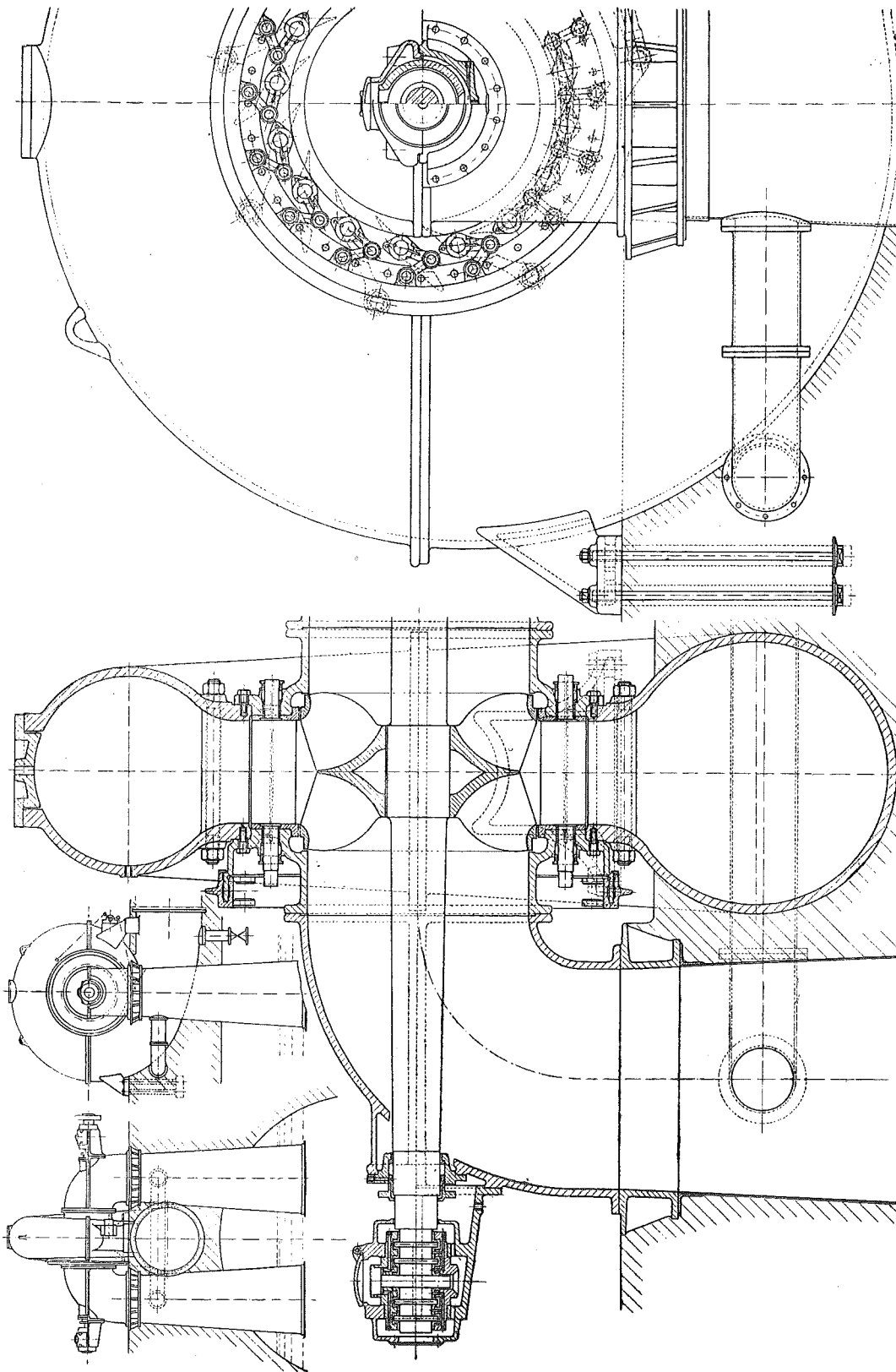


FIG. 40.

$N_e = 3500$ $Q = 6 \text{ m}^3/\text{sec}$ $H' = 50$ $N = 500$ $R = 0,6$ Echelles : $1/25$ et $1/125$

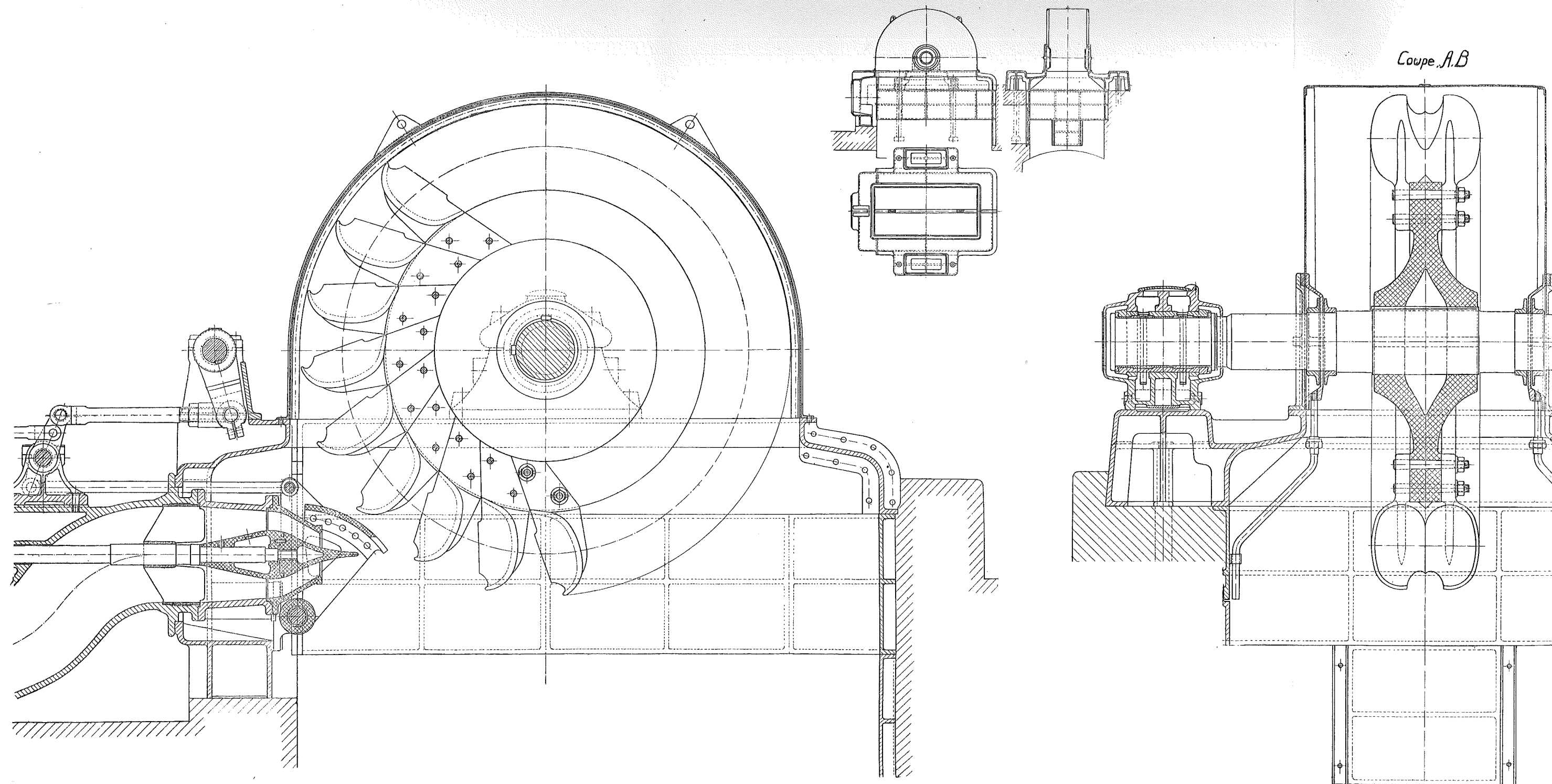


FIG. 41. — $N_c = 7000$ $Q = 2,12 \text{ m}^3/\text{sec}$ $H' = 320$ $N = 300$ $R = 0,002$ Echelles : 1/25 et 1/125

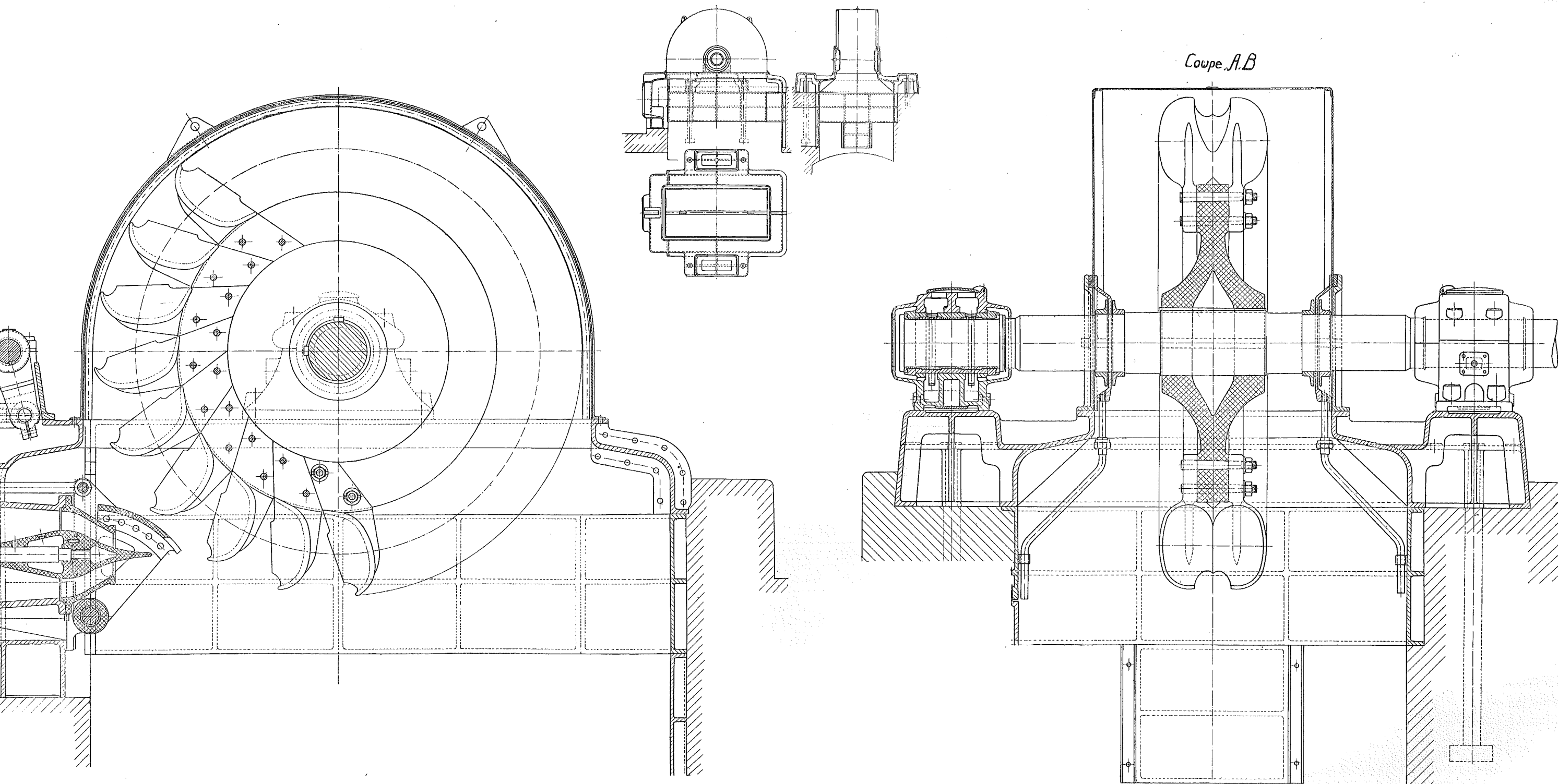


FIG. 41. — $N_e = 7000$ $Q = 2,12 \text{ m}^3/\text{sec}$ $H' = 320$ $N = 300$ $R = 0,002$ Echelles : 1/25 et 1/125

POMPES

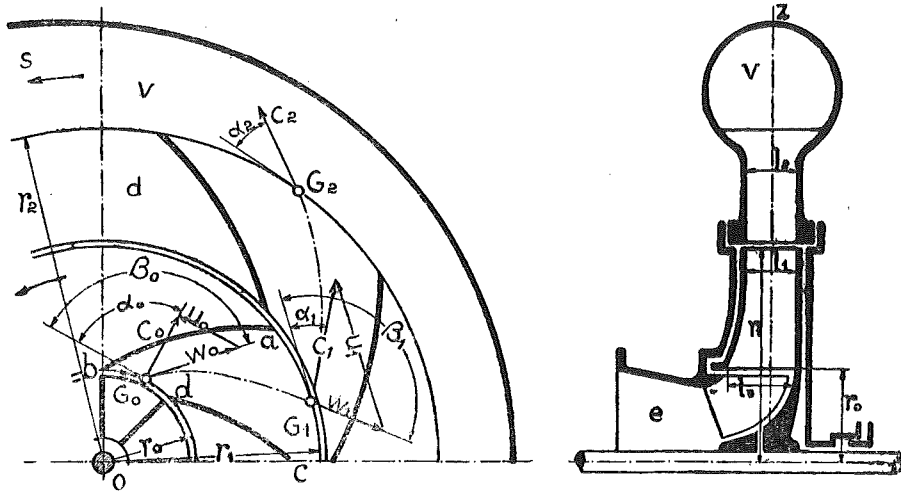


FIG. 42.

$$m = \frac{r_0}{r_1} \quad \epsilon = \frac{l_1}{r_1} \quad v = \frac{l_0}{l_1} \quad n = \frac{\delta_1}{\delta_0} \cdot \frac{1}{m} \cdot \frac{1}{v} \cdot \frac{\sin \beta_1}{\sin \beta_0}$$

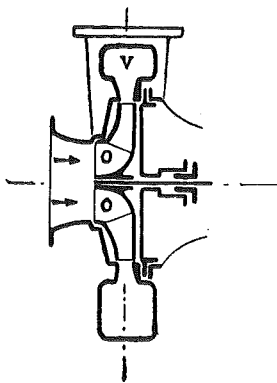


FIG. 43.

Pompe centrifuge

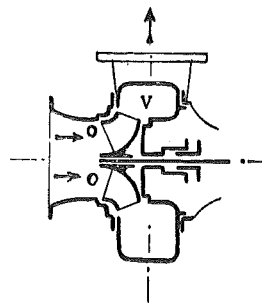


FIG. 44.

Pompe hélicocentrifuge

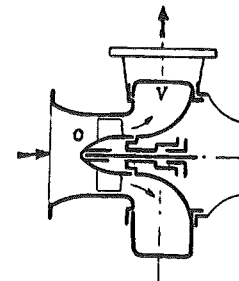


FIG. 45.

Pompe hélicotde

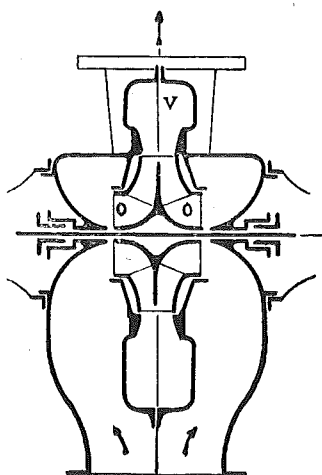


FIG. 46.
Pompe à double oute

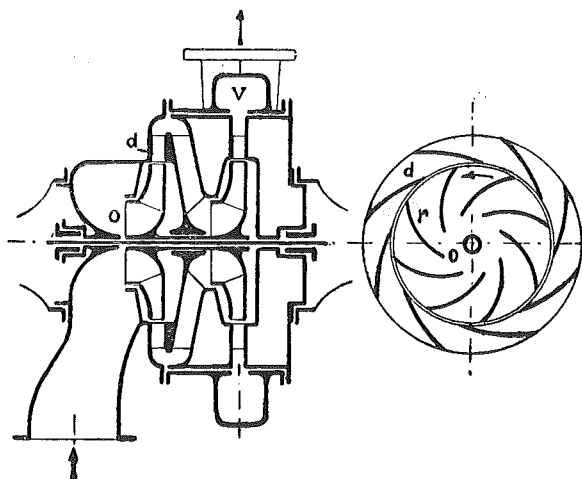


FIG. 47.
Pompe multicellulaire

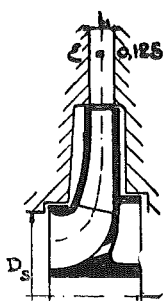


FIG. 48.
Pompe centrifuge THP
R = 4 à 12,5

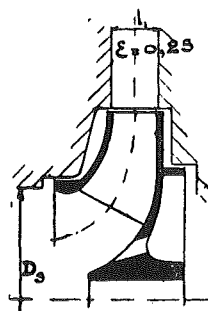


FIG. 49.
Pompe hélicocentrifuge HP
R = 12,5 à 25

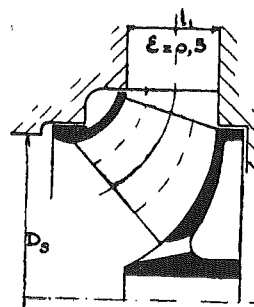


FIG. 50.
Pompe hélicocentrifuge MP
R = 25 à 50

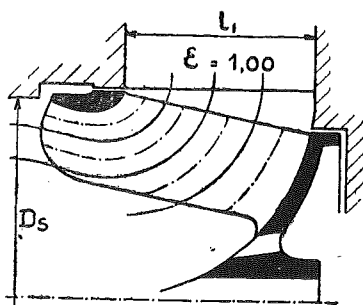


FIG. 51.
Pompe mixte BP
R = 50 à 100

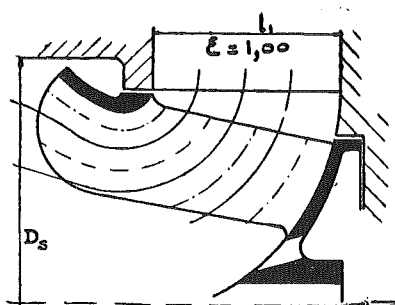


FIG. 52.
Pompe mixte TBP
R = 100 à 200

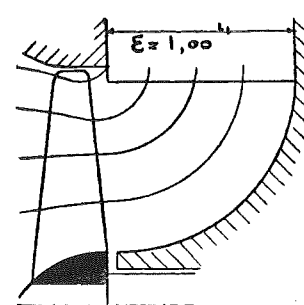


FIG. 53.
Pompe hélicoïde TTBP
R = 200 à 3000 (7000 ventilateur)

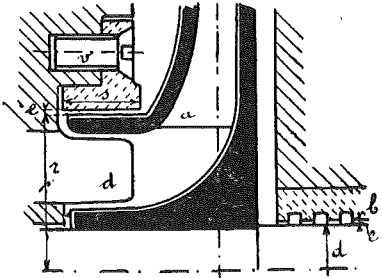


FIG. 54.

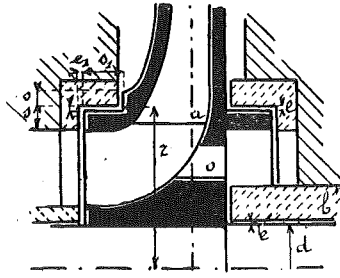


FIG. 55.

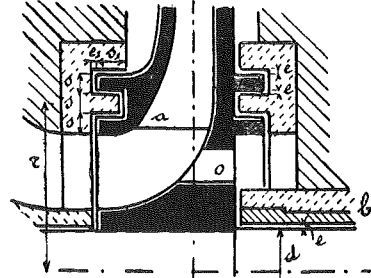


FIG. 56.

Dispositifs d'étanchéité

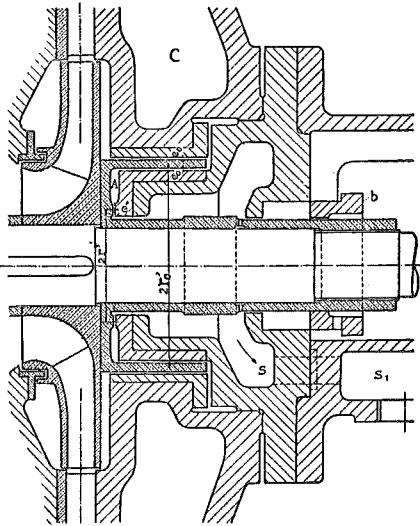


FIG. 57.

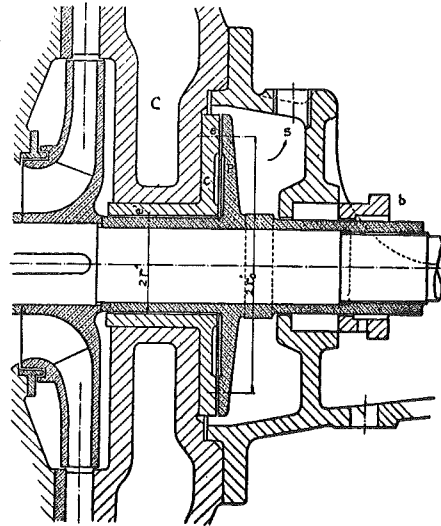


FIG. 58.

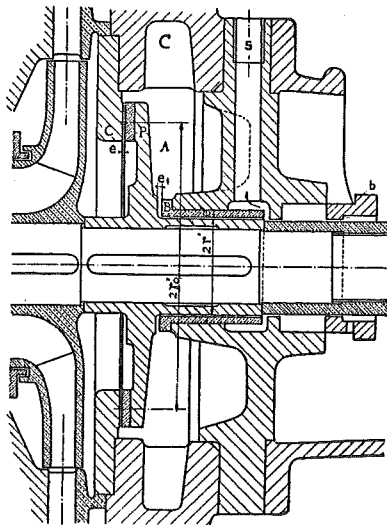


FIG. 59.

Dispositifs d'équilibrage

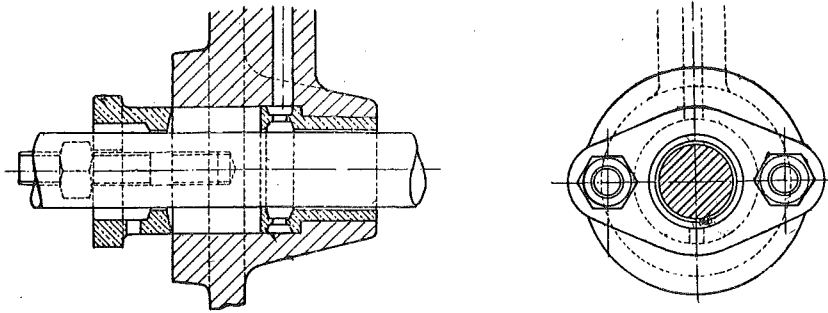


FIG. 60.

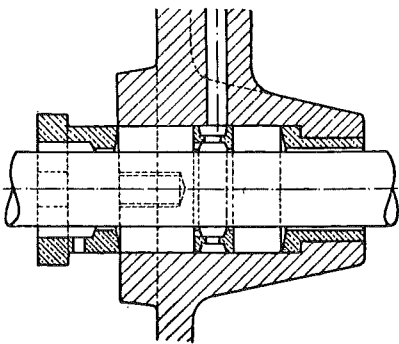


FIG. 61.

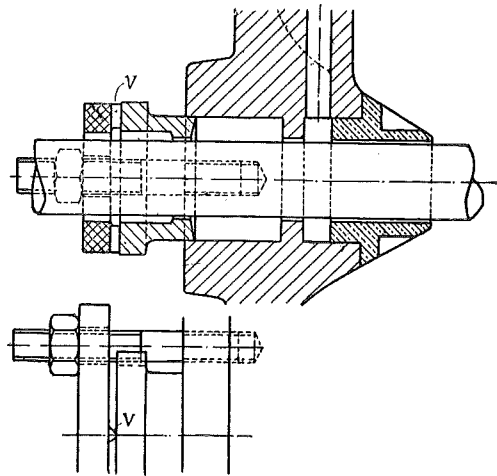


FIG. 62.

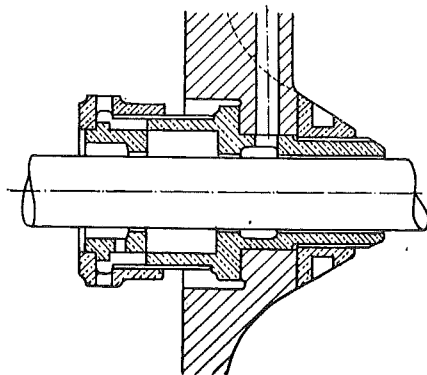


FIG. 63.

Boîtes à bourrage

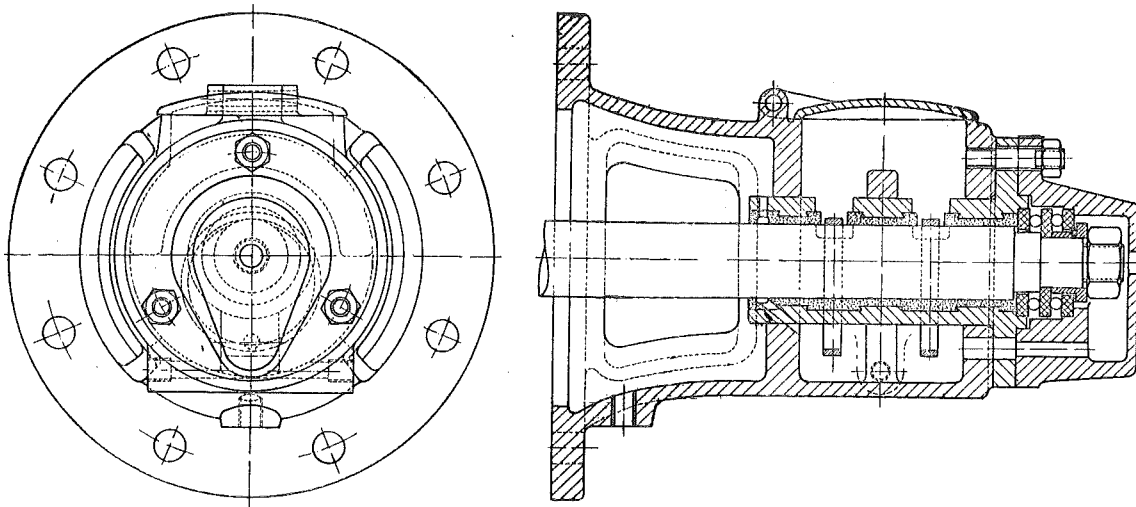


FIG. 64.

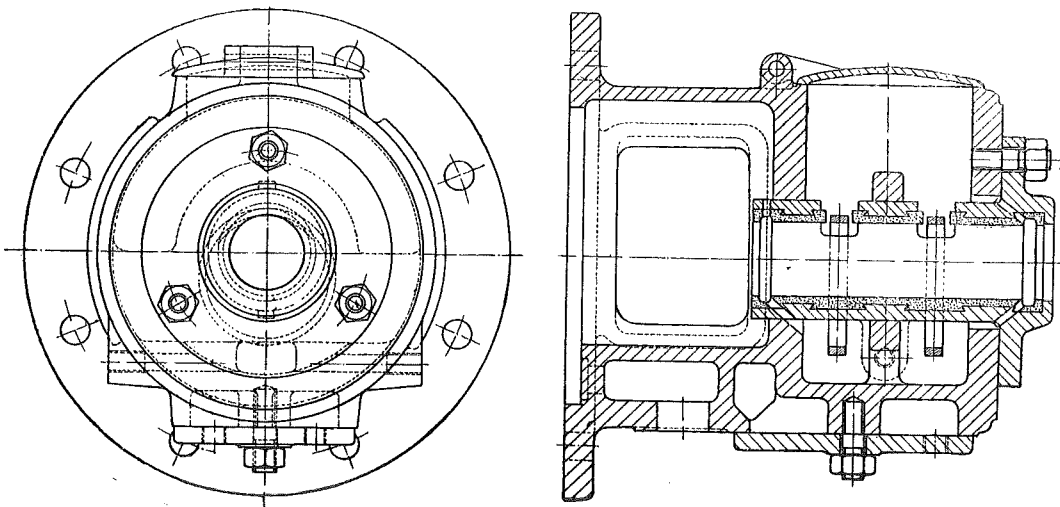


FIG. 65.

Paliers

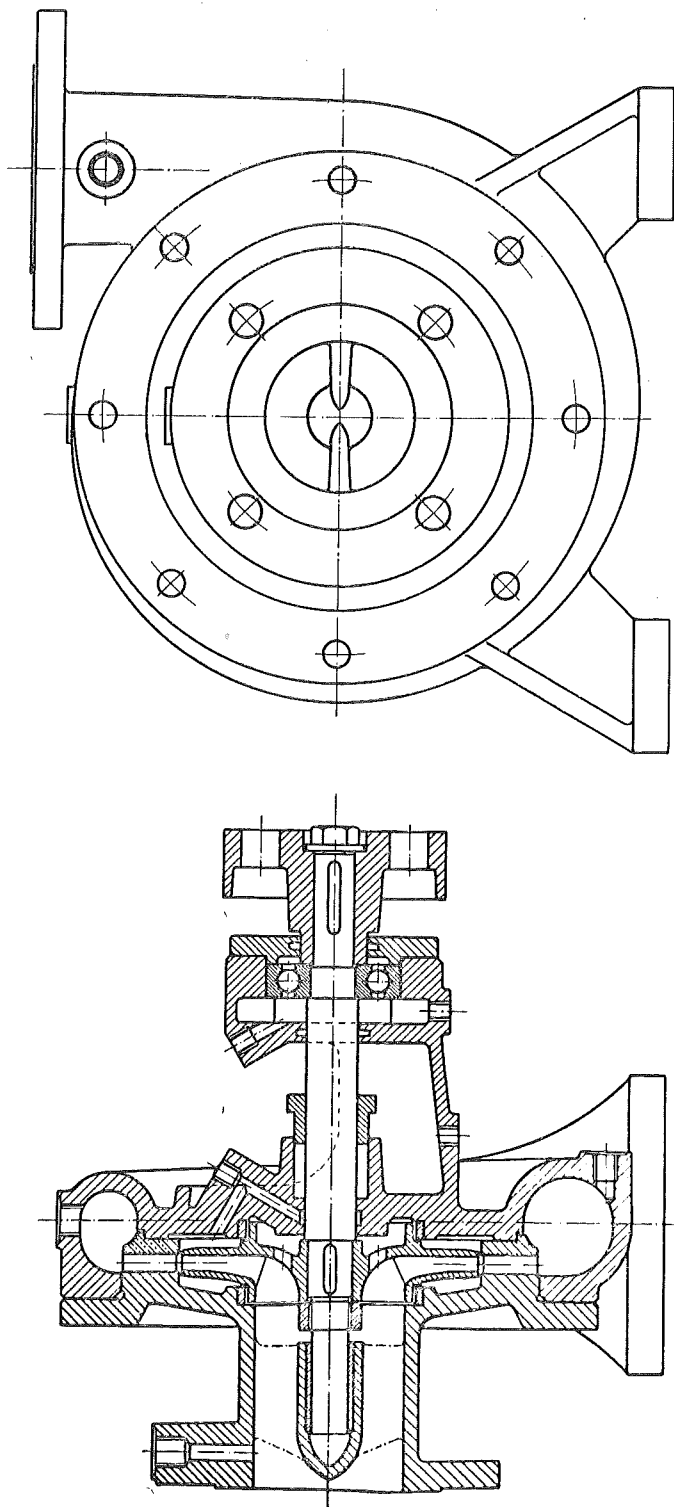


FIG. 66.
Q = 75 m³/h H' = 55 N = 2920 R = 5,3 Echelle : 1/5

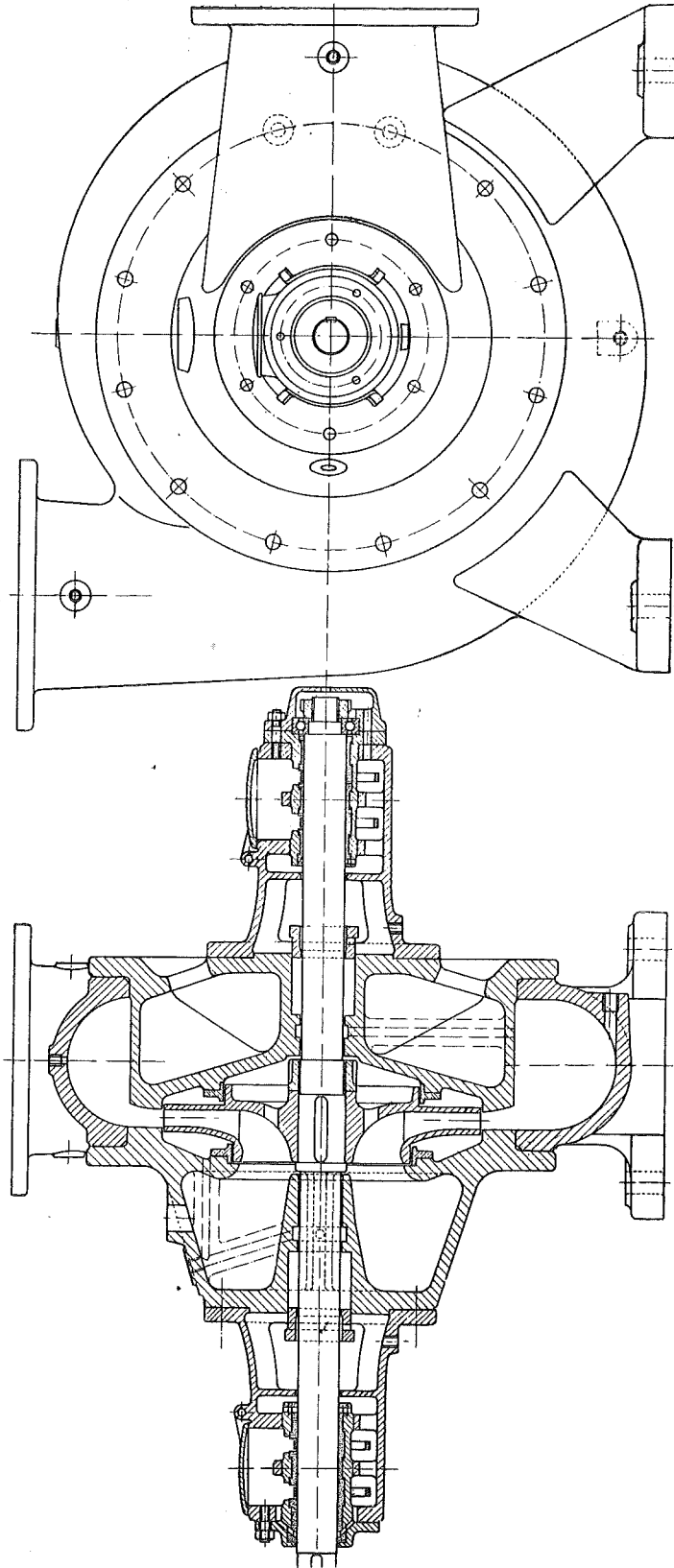


Fig. 67.

$Q = 500 \text{ m}^3/\text{h}$ $H' = 50$ $N = 1450$ $R = 10$ Echelle : 1/10

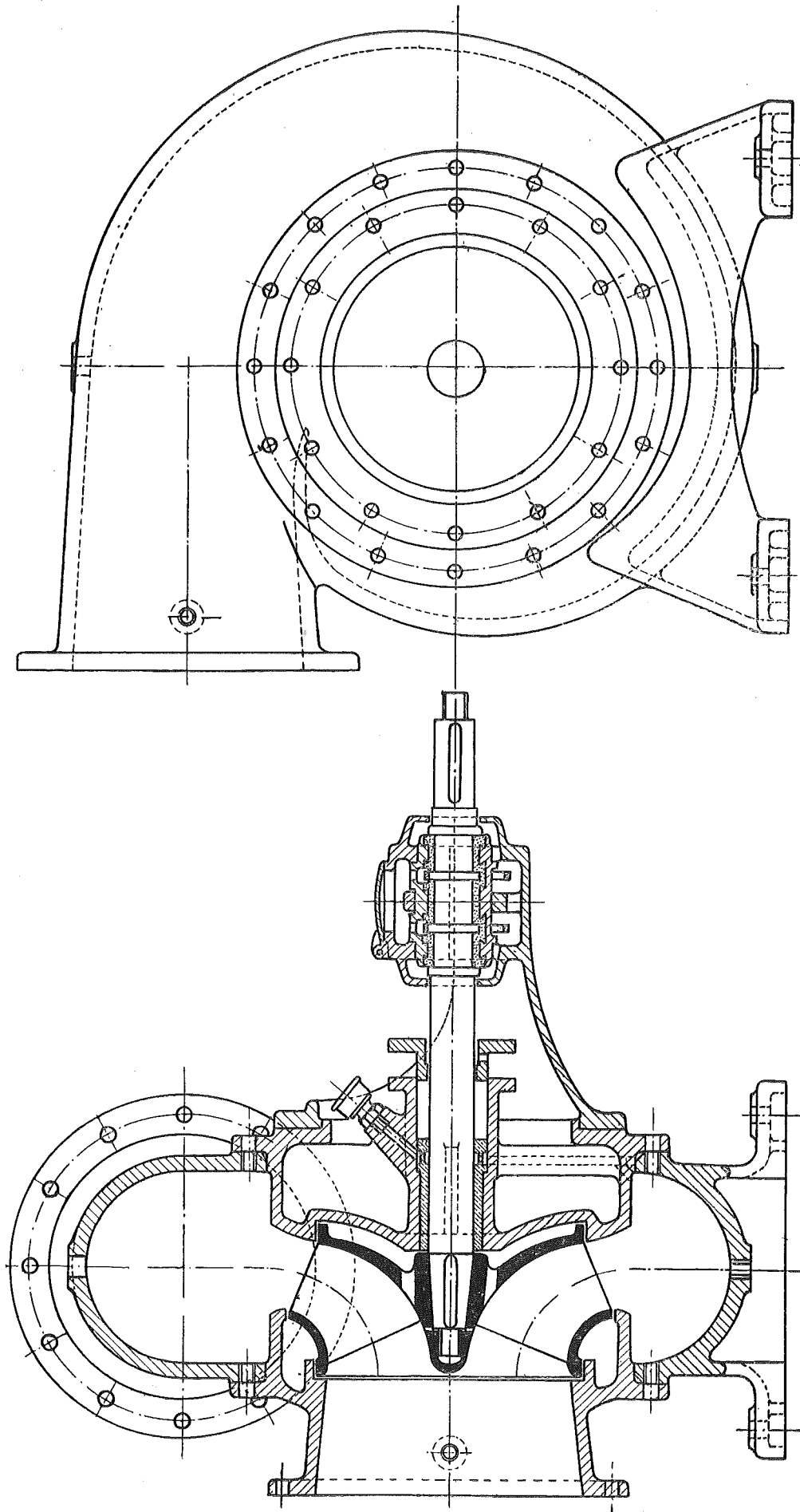


FIG. 68. $Q = 1500 \text{ m}^3/\text{h}$ $H' = 12,50$ $N = 730$ $R = 59$ Echelle : 1/10

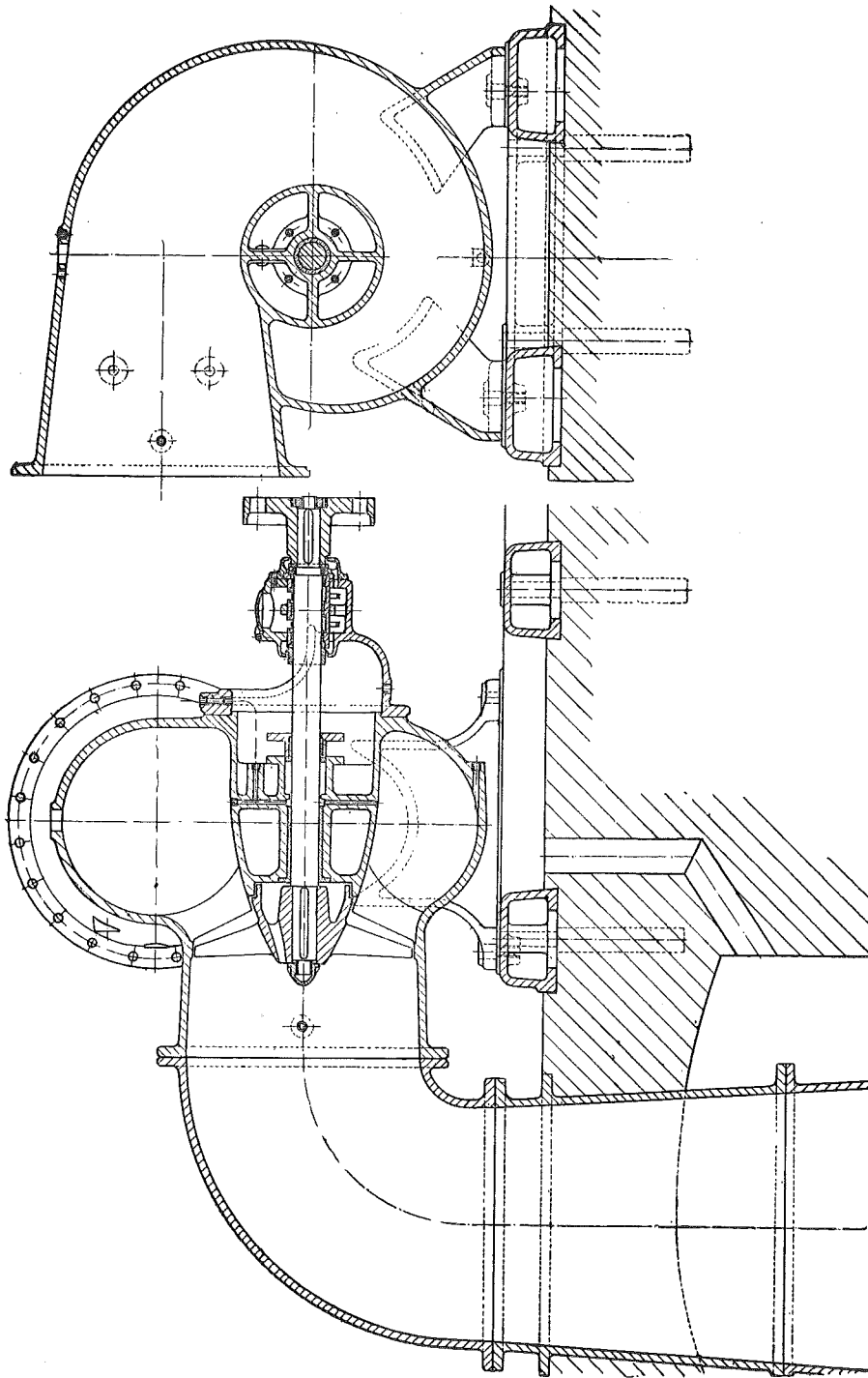


FIG. 69.
Q = 6000 m³/h H' = 6.50 N = 585 R = 400 Echelle : 1/25

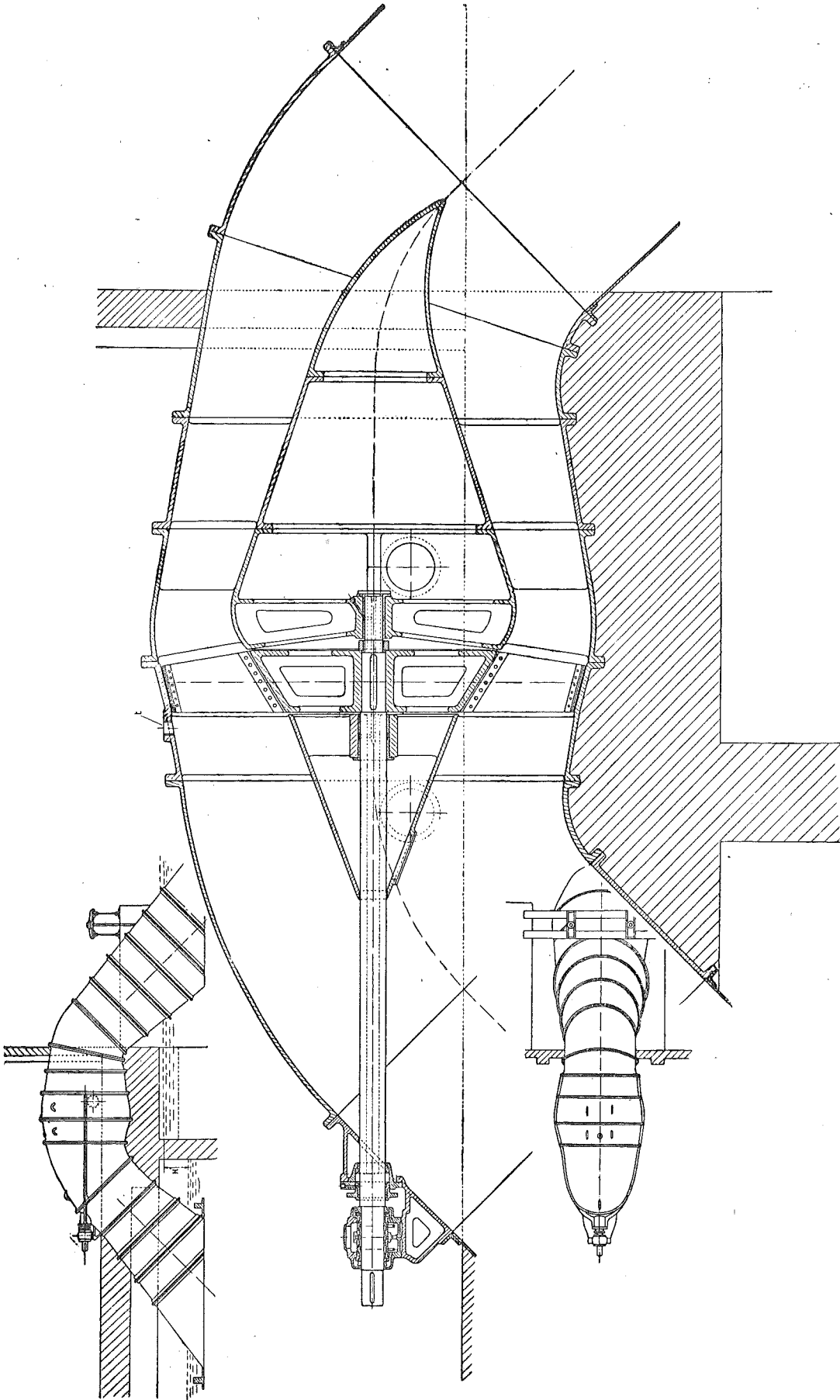


FIG. 70. Q = 60.000 m³/h H' = 1,20 N = 54 R = 425 Echelle : 1/50

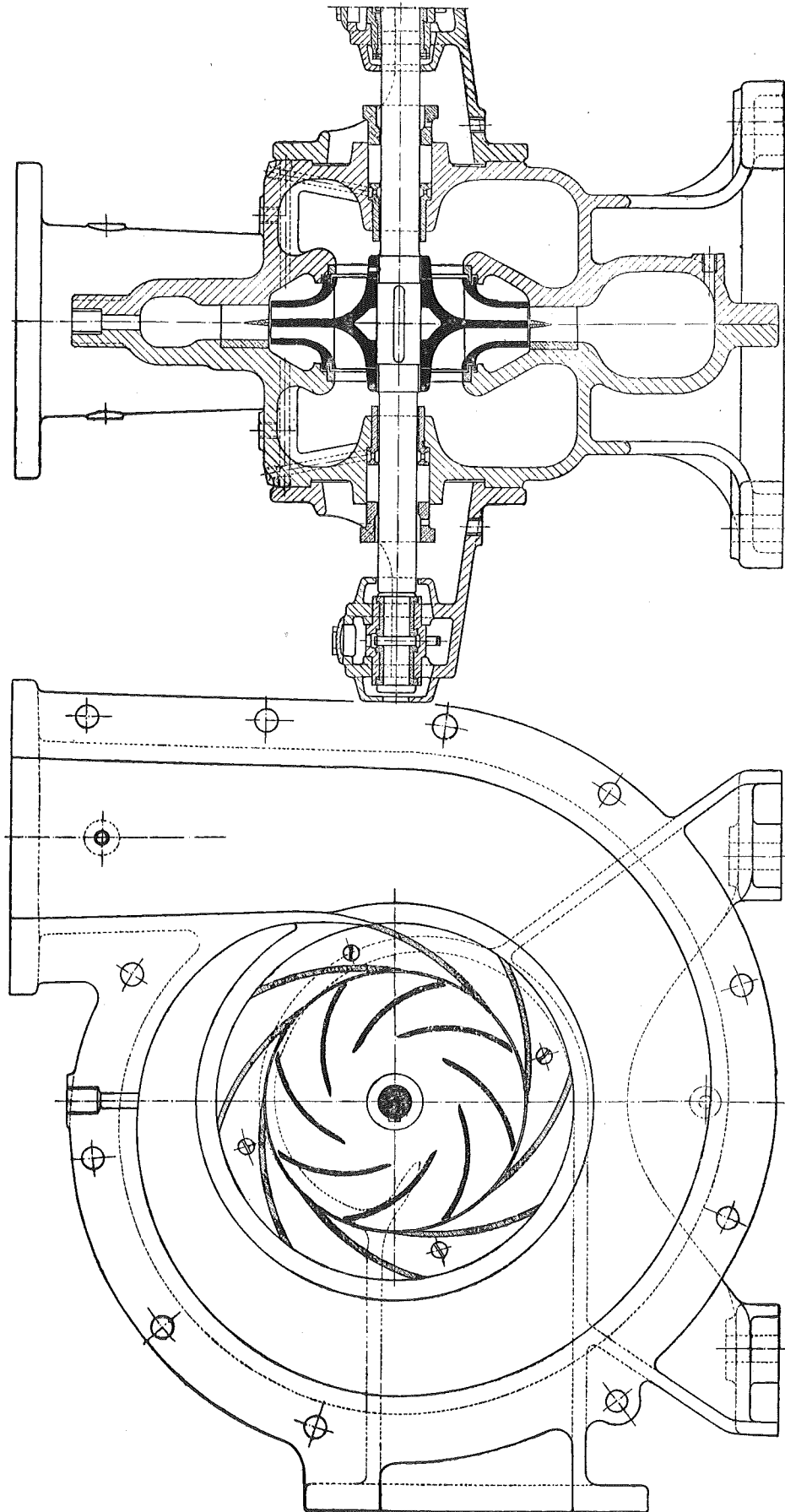


Fig. 71.

$Q = 150 \text{ m}^3/\text{h}$ $H' = 55$ $N = 2920$ $R \text{ par roue} = 5,3$ $R \text{ total} = 10,6$ Echelle : 1/5

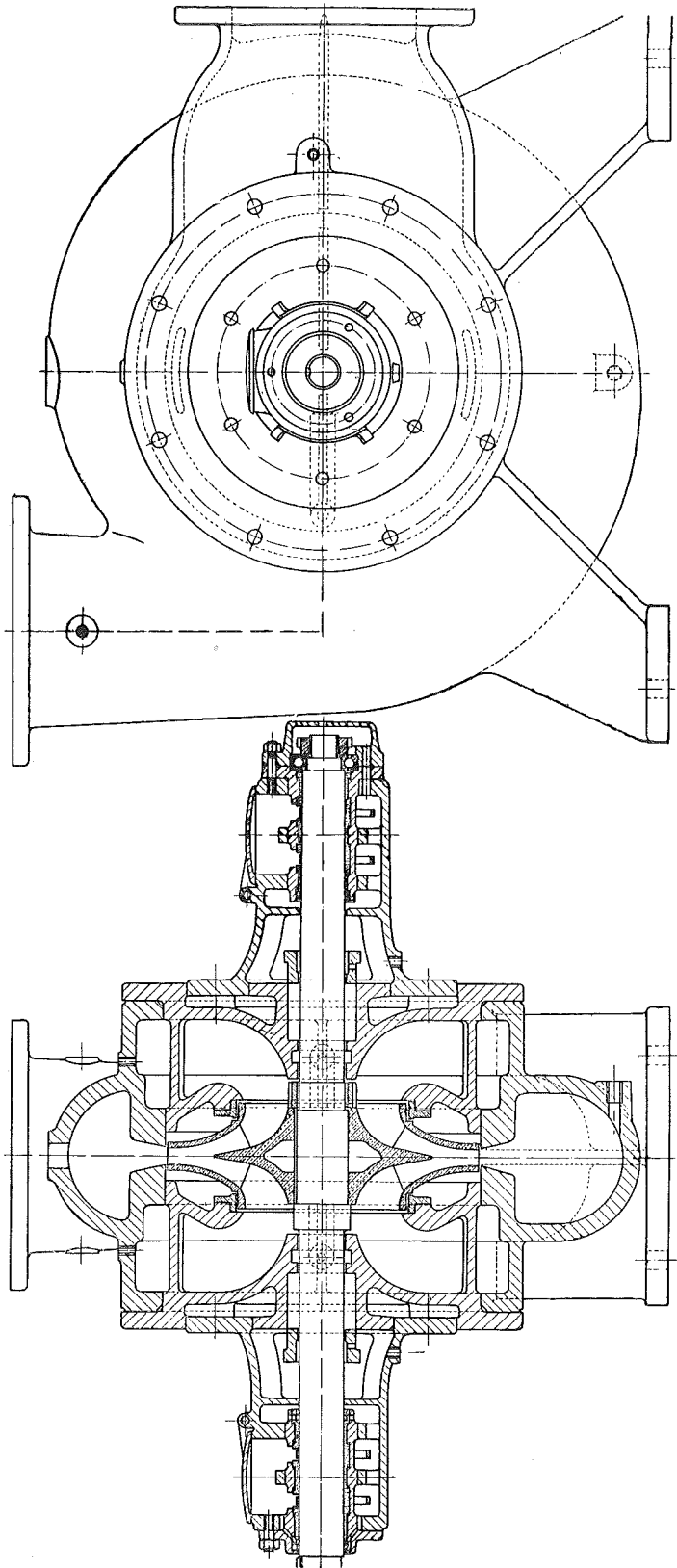


FIG. 72.

Q = 500 m³/h H' = 50 N = 1450 R par roue = 5 R total = 10 Echelle : 1/10

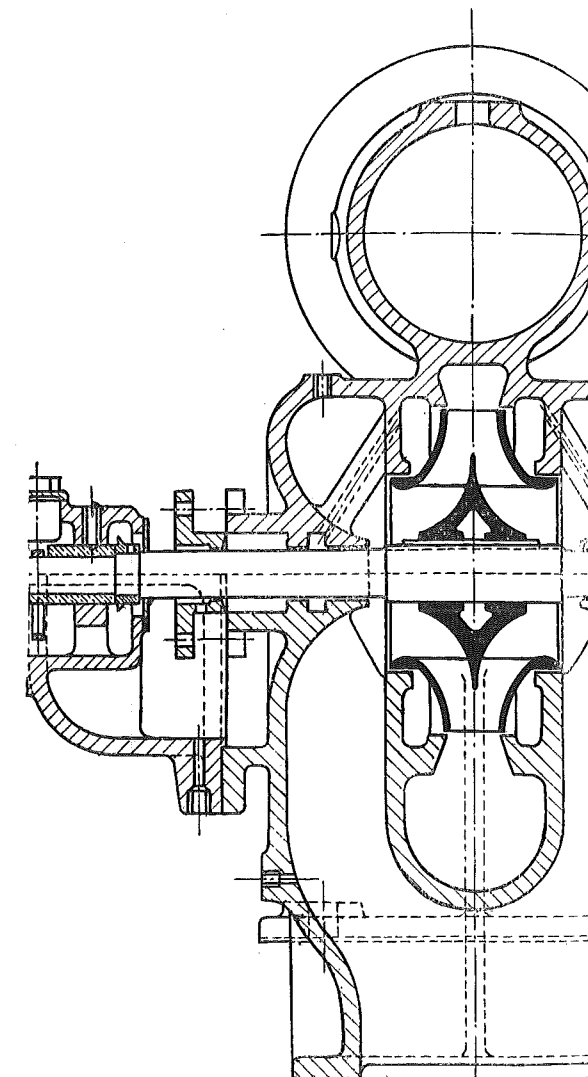
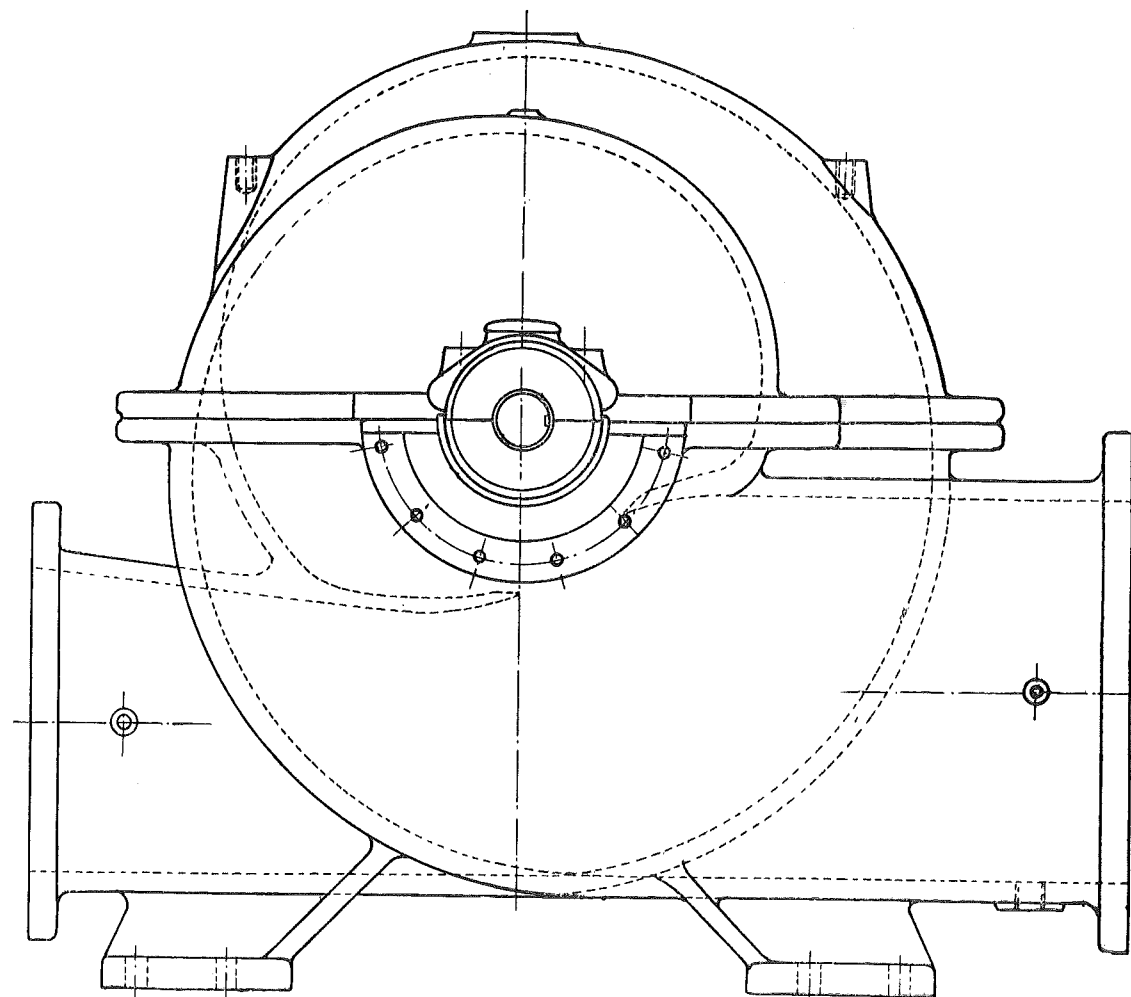
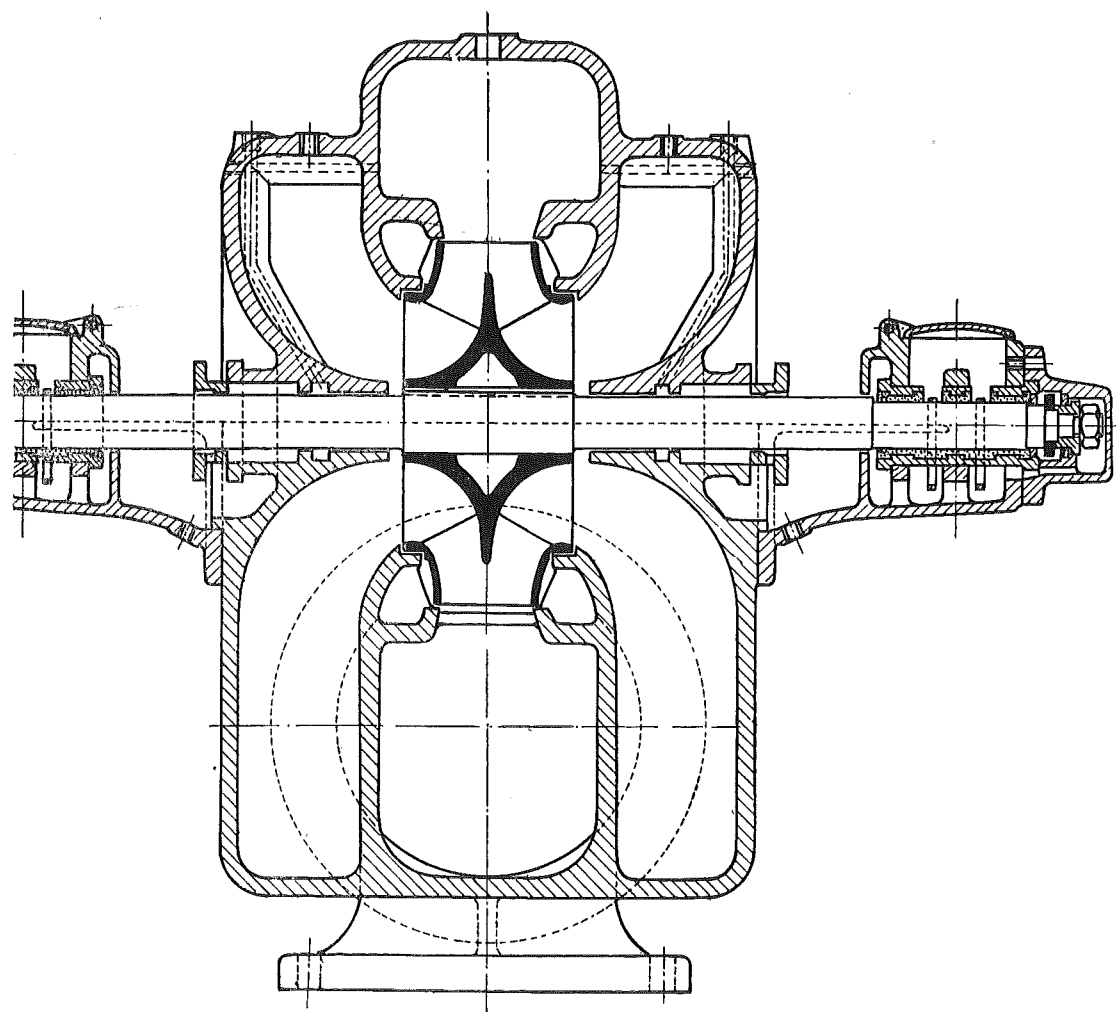
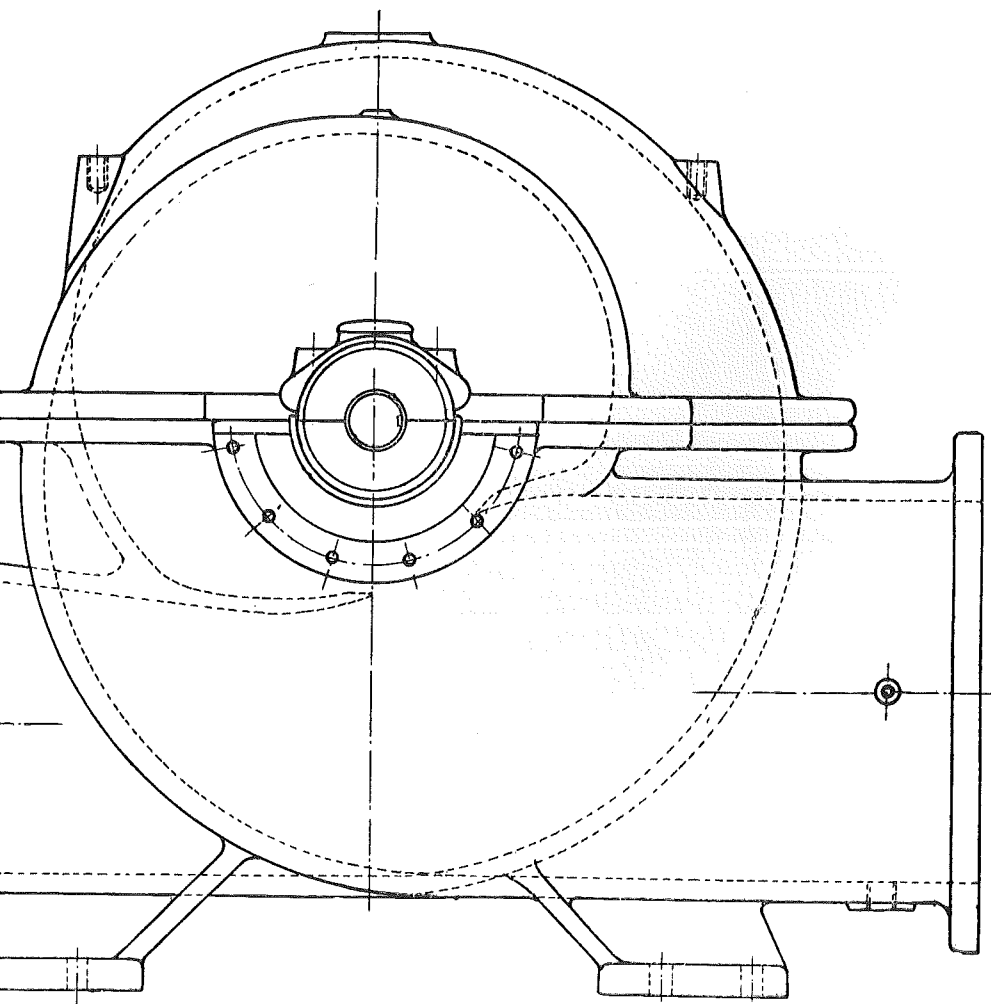


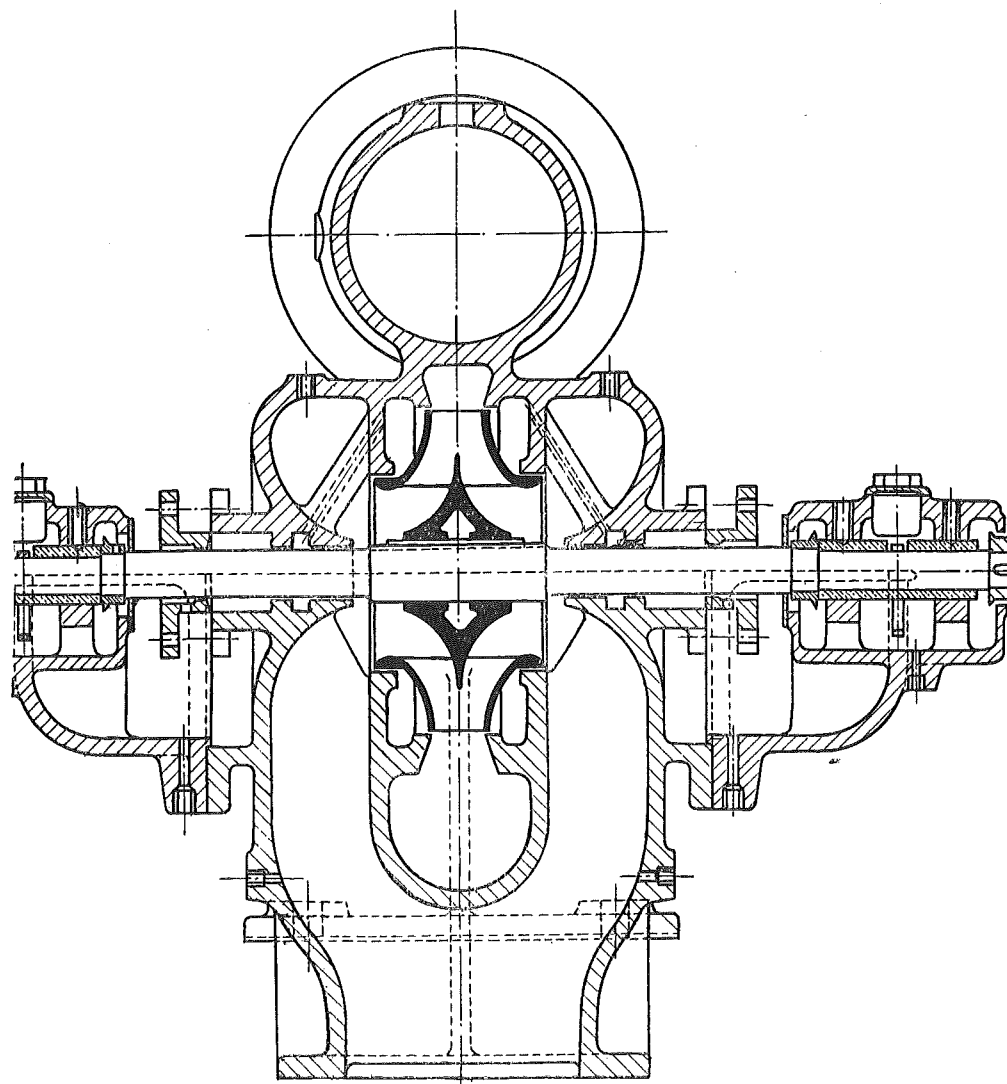
FIG. 73.

$Q = 1500 \text{ m}^3/\text{h}$ $H' = 12,50$ $N = 730$ $R \text{ par roue} = 29,5$ $R \text{ total} = 59$ Echelle : 1/10

$Q = 750 \text{ m}^3/\text{h}$



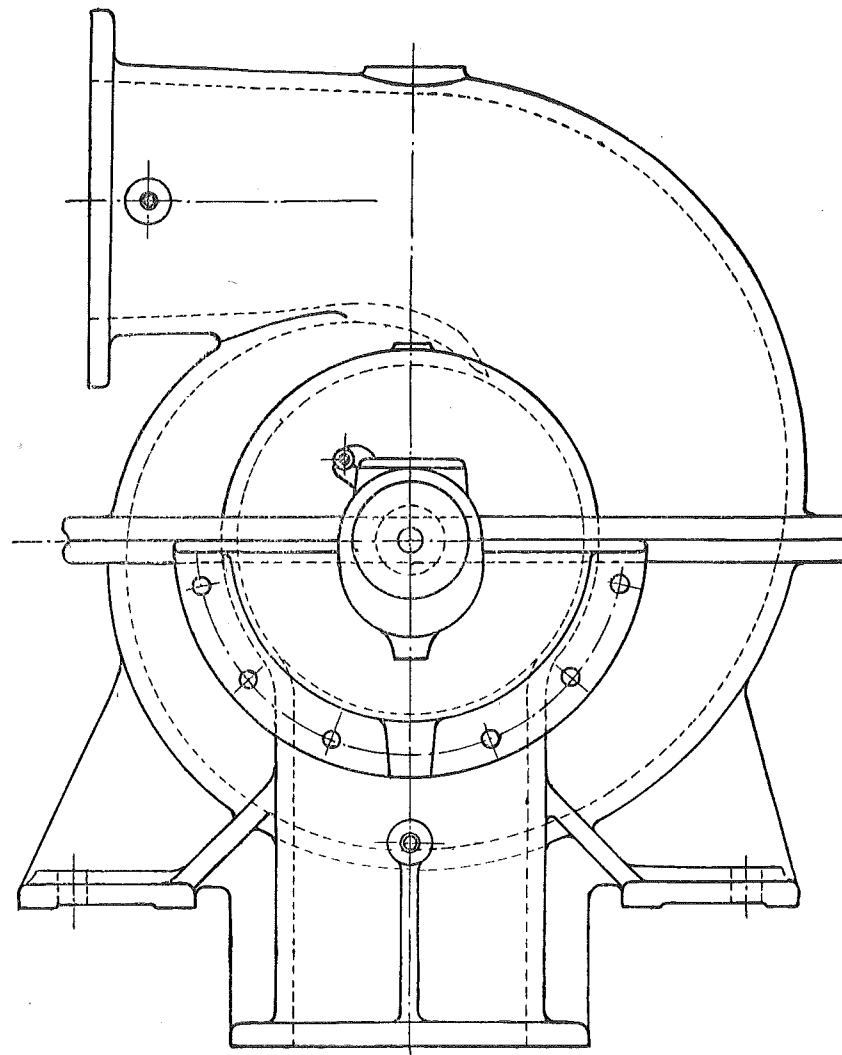
29,5 R total = 59 Echelle : 1/10



$Q = 750 \text{ m}^3/\text{h}$ $H' = 12,50$ $N = 730$

FIG. 74.

R par roue = 14,75 R total = 29,5 Echelle : 1/10



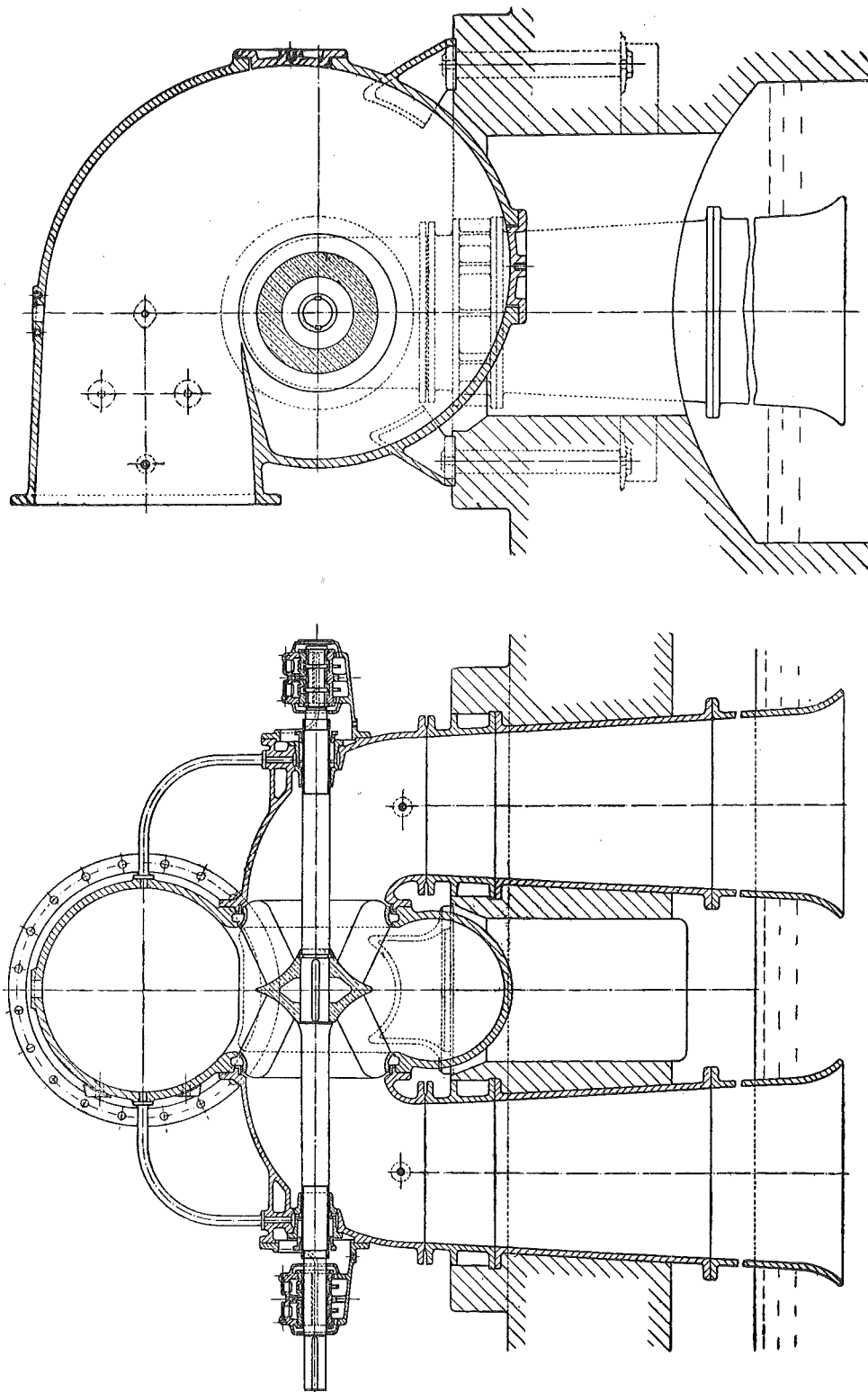


Fig. 75.

$Q = 6000 \text{ m}^3/\text{h}$ $H' = 6,50$ $N = 585$ $R \text{ par roue} = 200$ $R \text{ total} = 400$ Echelle : 1/25

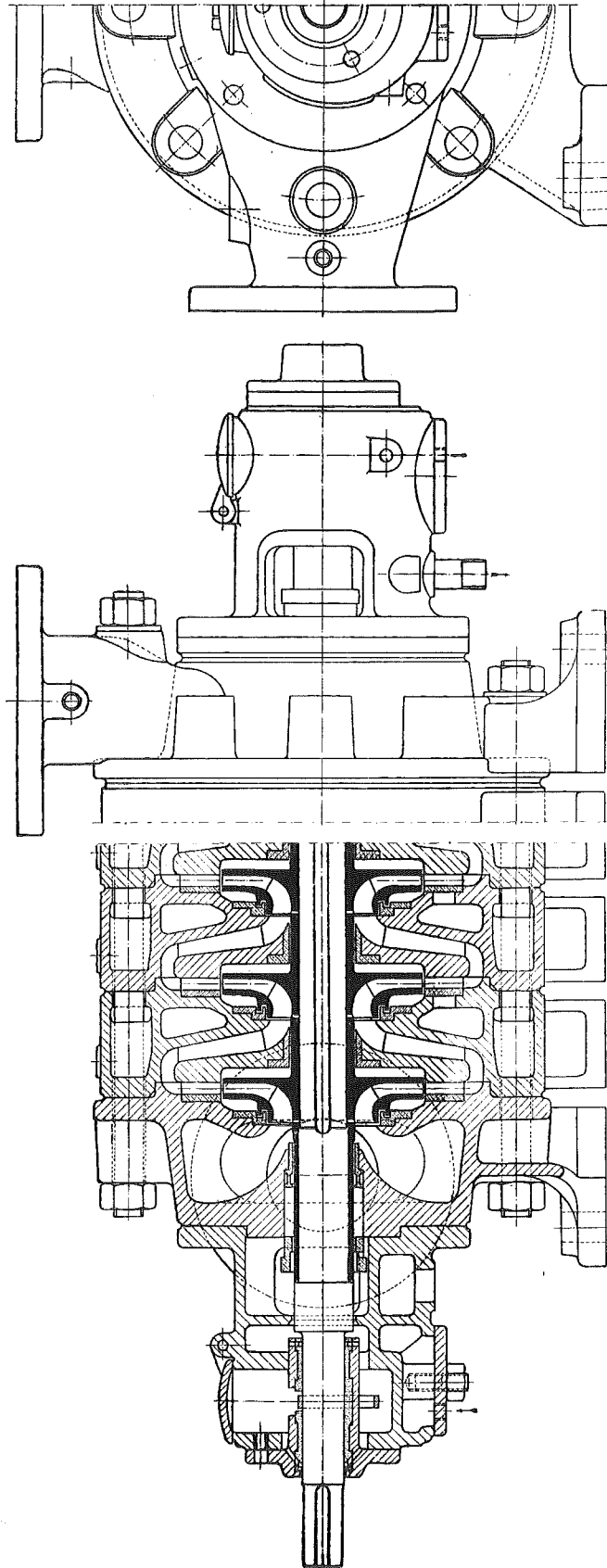


FIG. 76. $Q = 25 \text{ m}^3/\text{h}$ $H' = 162$ $N = 2920$ $R \text{ par roue} = 5,3$ $R \text{ total} = 0,36$ Echelle : 1/5

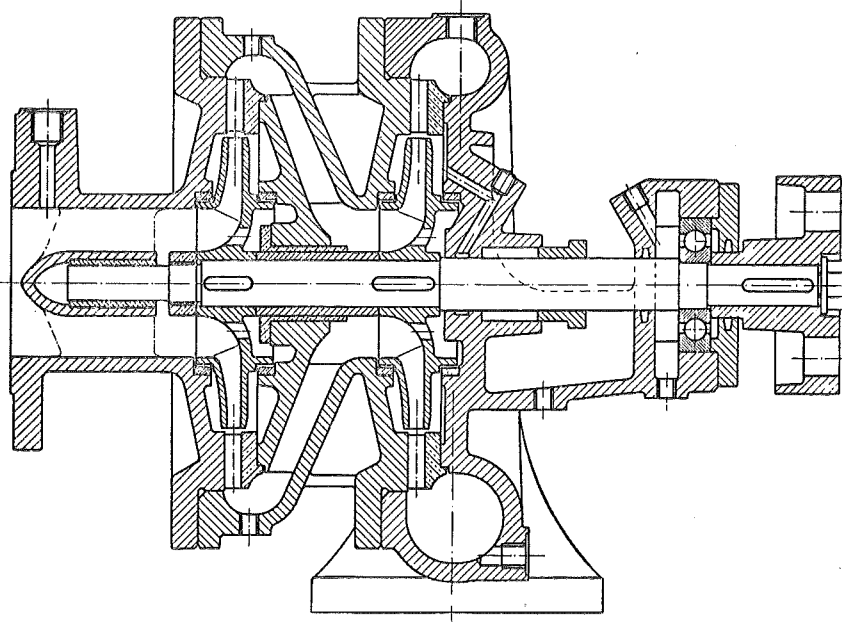


FIG. 77.

$Q = 75 \text{ m}^3/\text{h}$ $H' = 110$ $N = 2920$ $R \text{ par roue} = 5,4$ $R \text{ total} = 1,87$ Echelle : 1/5

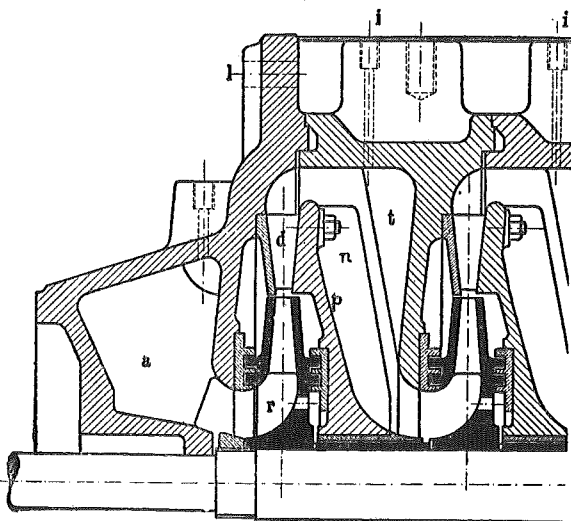


FIG. 78.

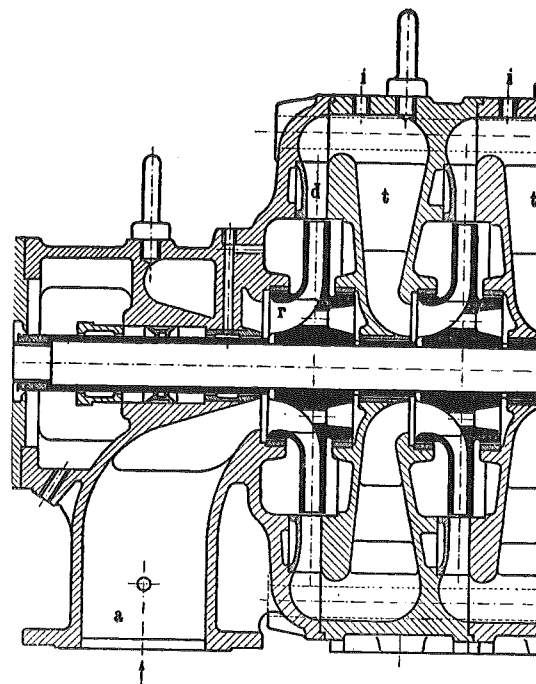


FIG. 79.

Pompe multicellulaire : type à éléments séparés

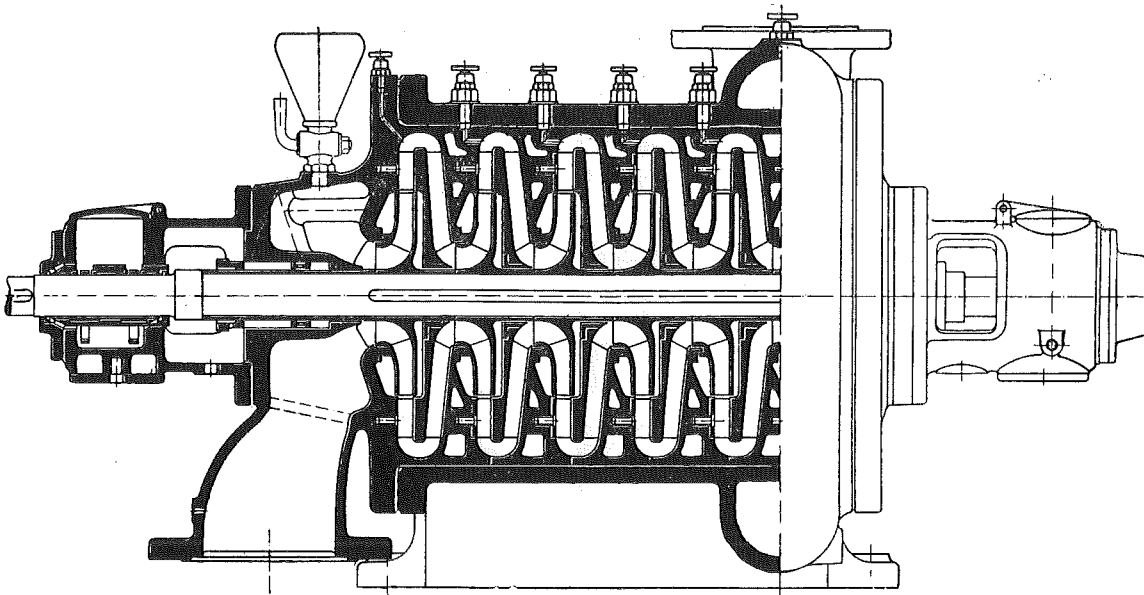


FIG. 80.

Pompe multicellulaire : type à enveloppe

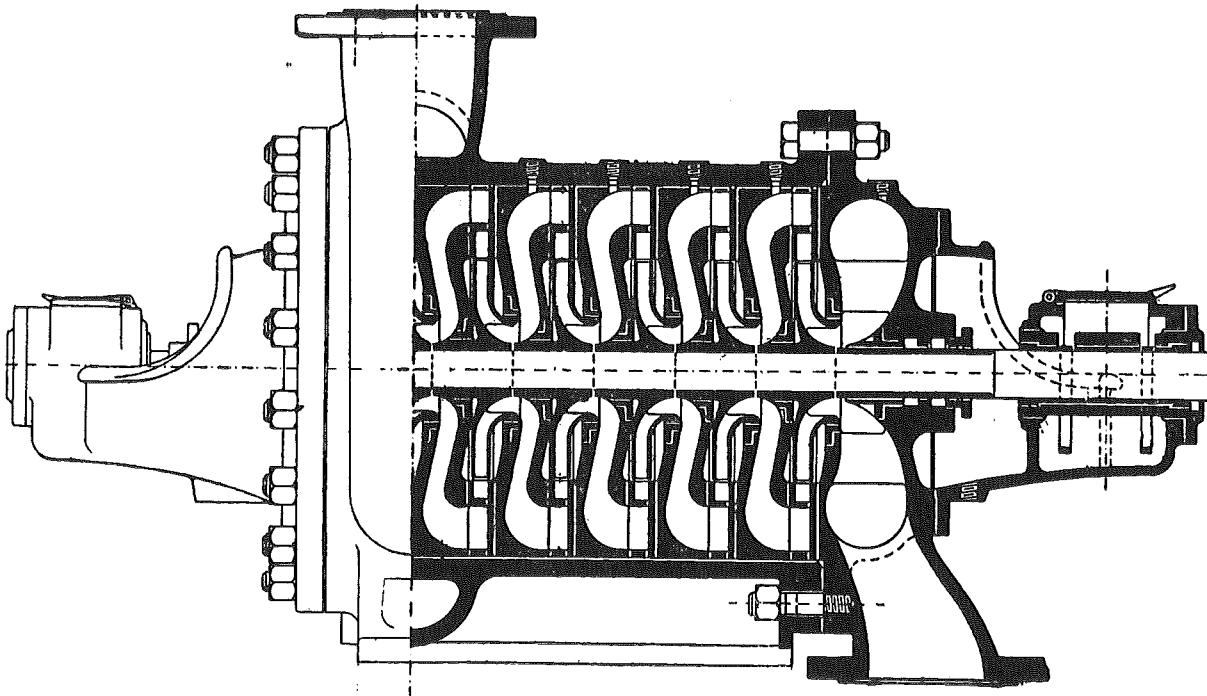


FIG. 81.

Pompe multicellulaire : type à enveloppe

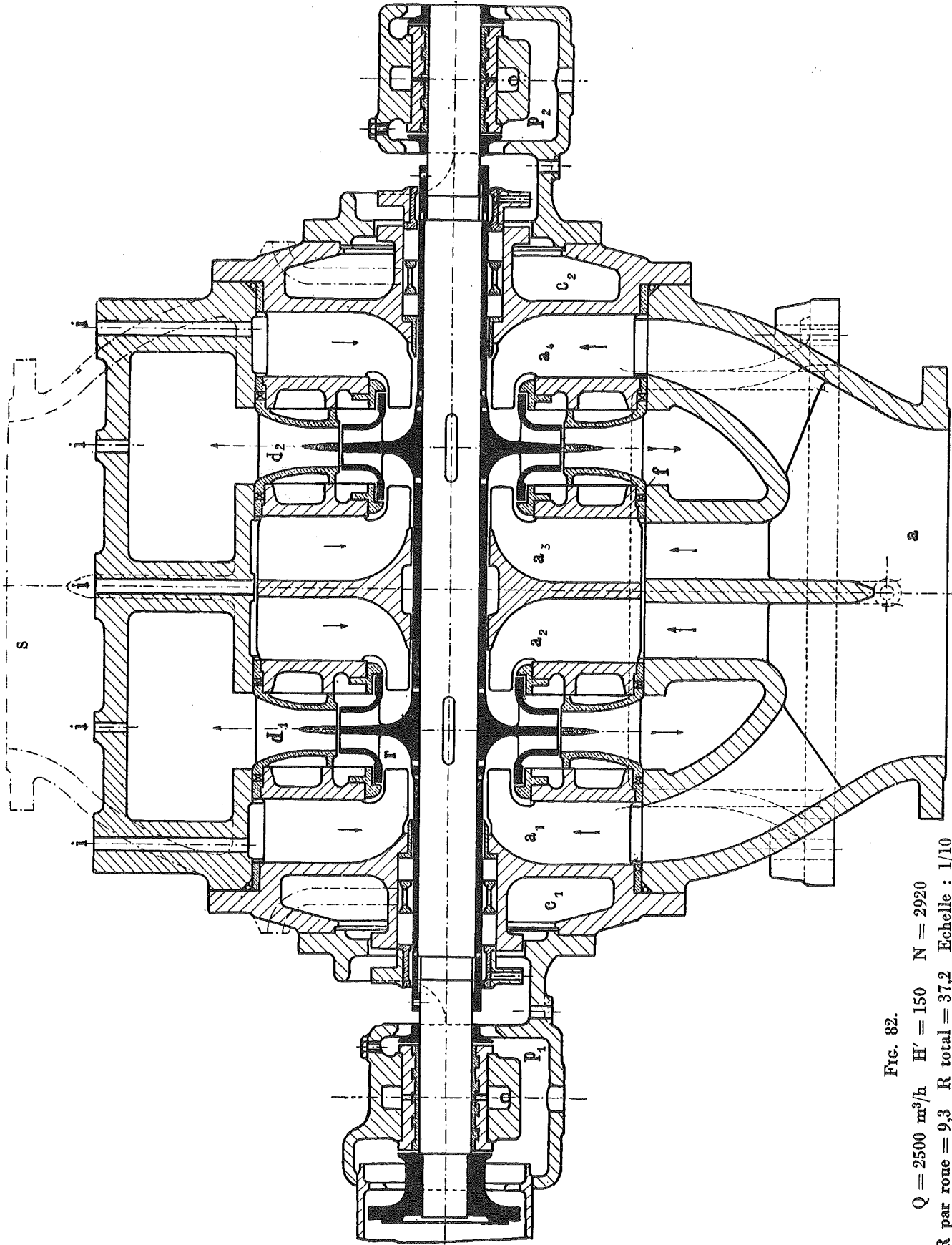


FIG. 82.

$Q = 2500 \text{ m}^3/\text{h}$ $H' = 150$ $N = 2920$
 $R \text{ par roue} = 9,3$ $R \text{ total} = 37,2$ Echelle : 1/10

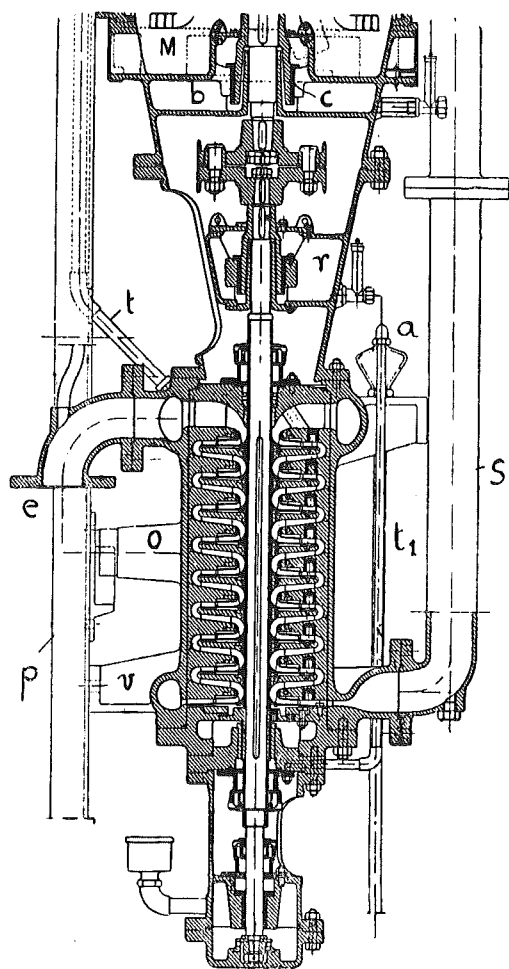


FIG. 83.
Pompe de fonçage

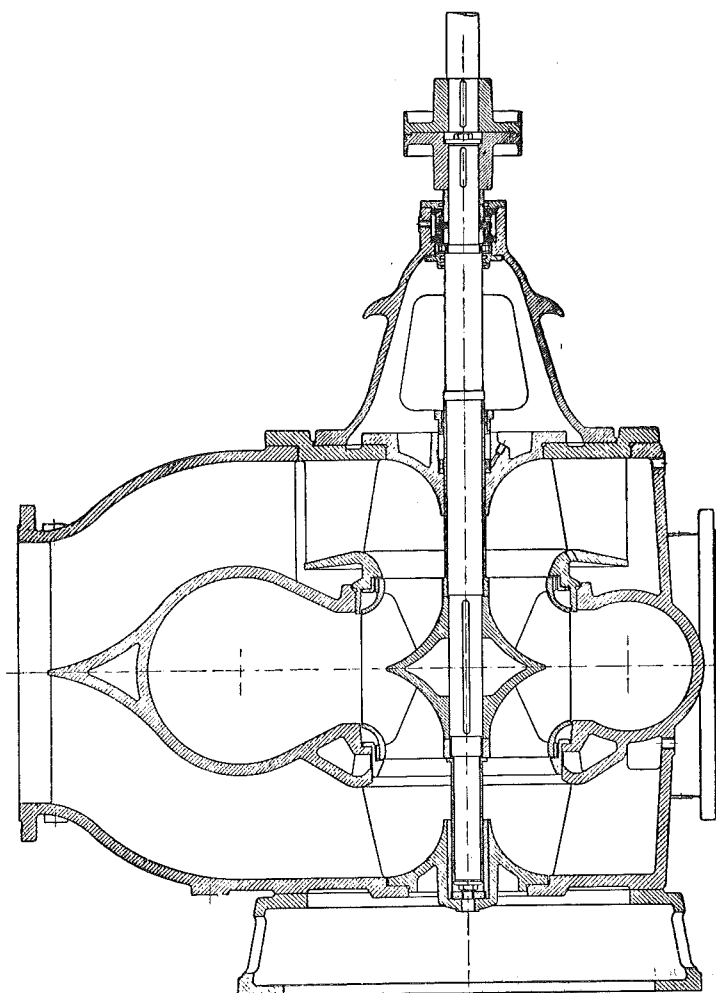
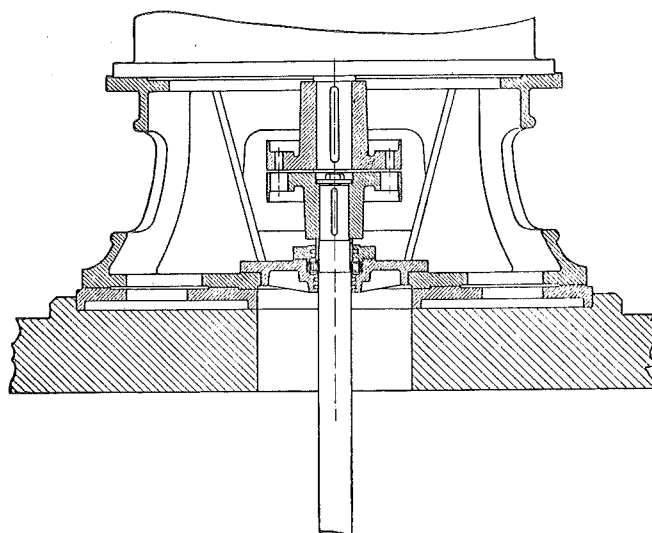


FIG. 84.
Pompe pour eaux d'égout

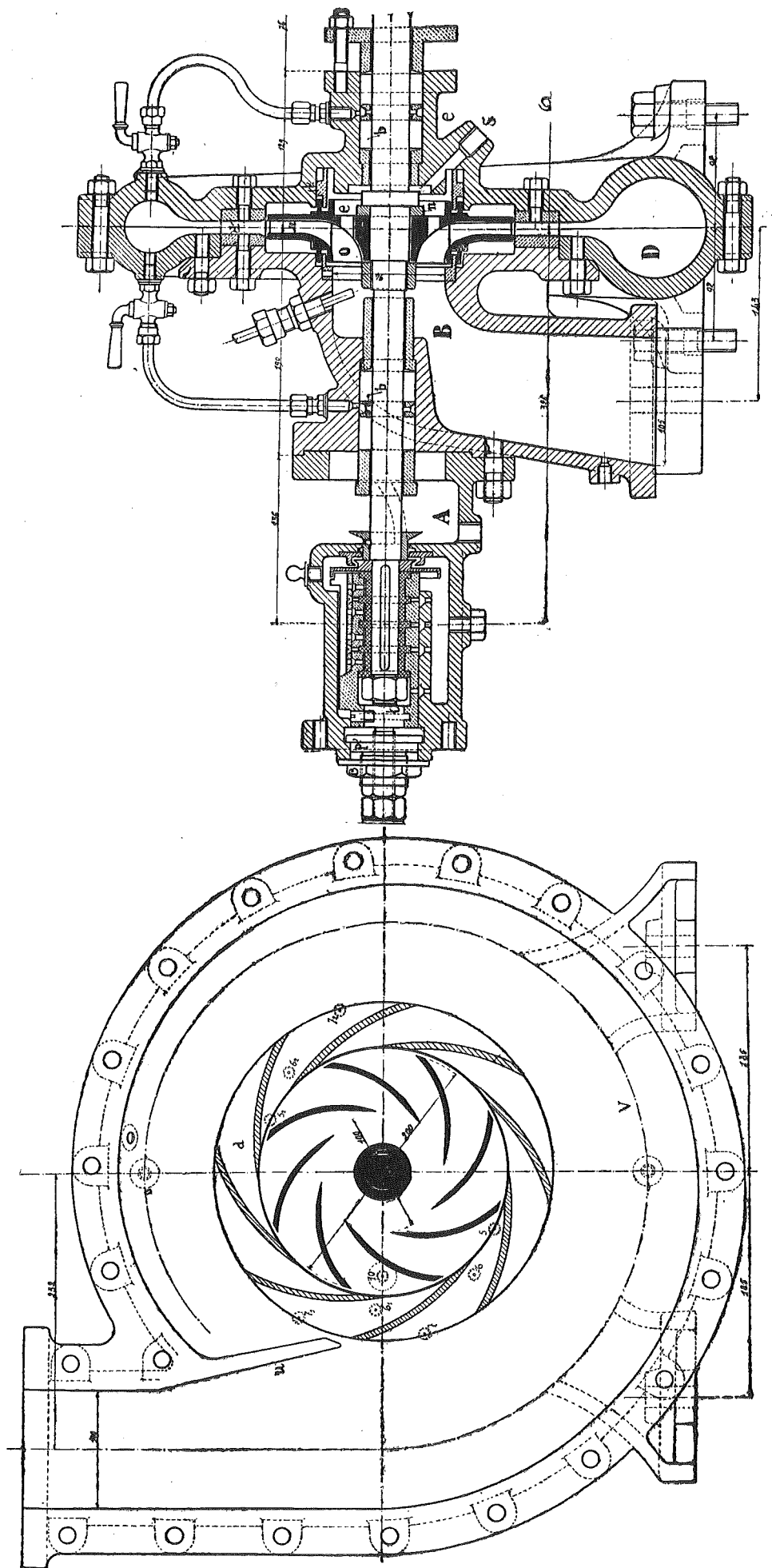


Fig. 85.
Pompe du laboratoire

VENTILATEURS

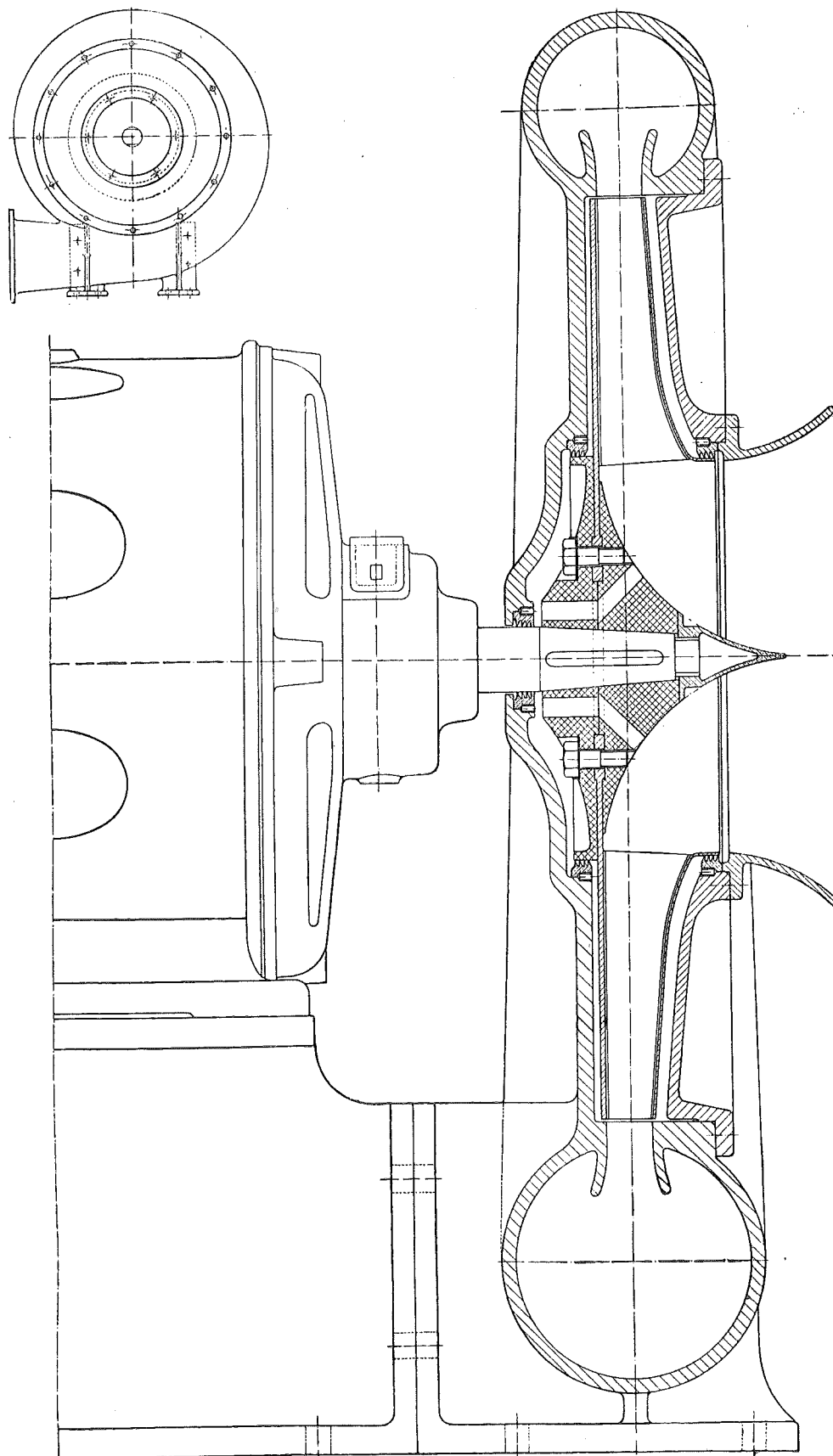


FIG. 86. — $Q = 1,83 \text{ m}^3/\text{sec}$ $h = 960 \text{ mm d'eau}$ $N = 2920$ $R = 8$ Echelle : 1/5

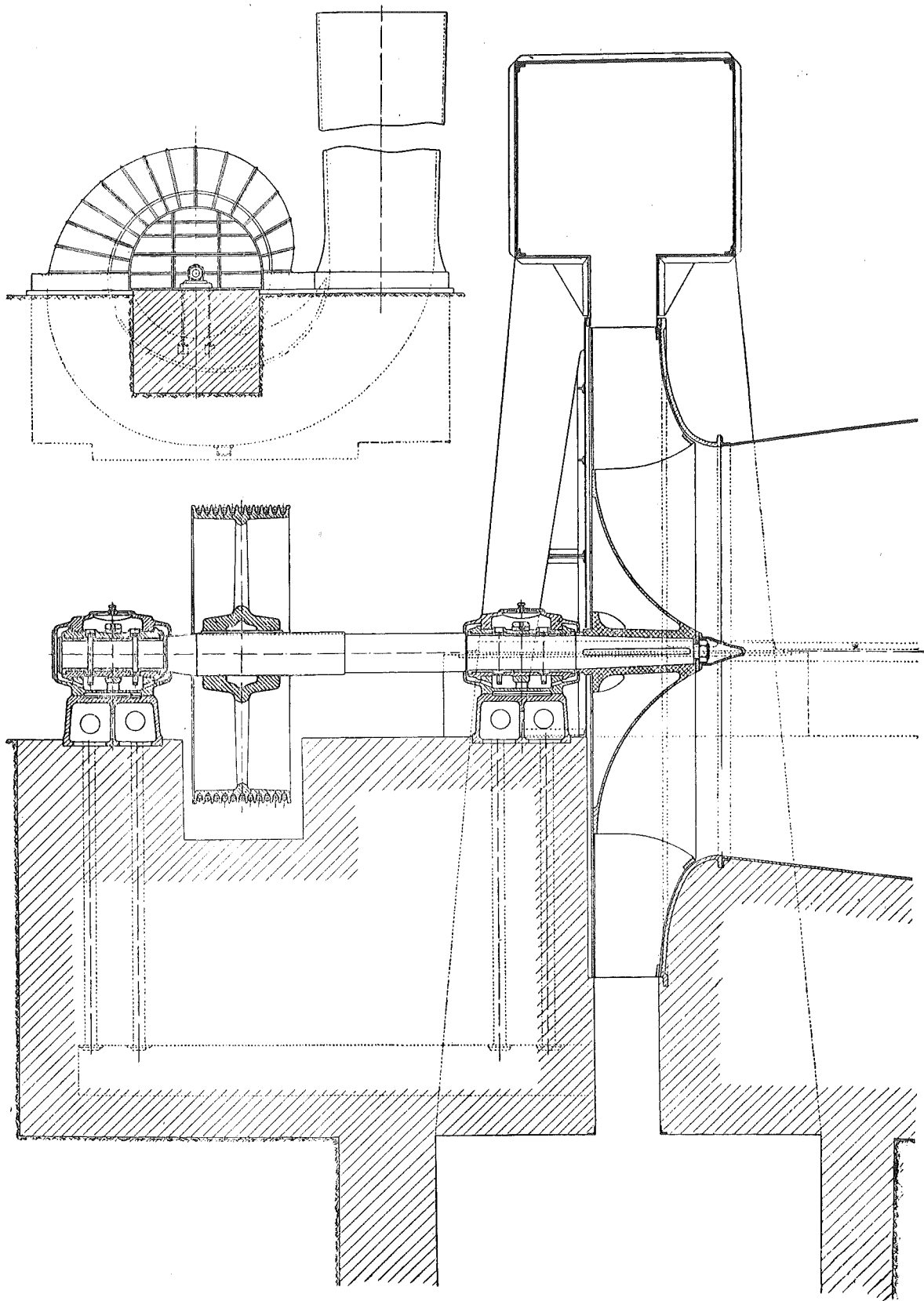


FIG. 87. — $Q = 13.000 \text{ m}^3/\text{min}$ $h = 240 \text{ mm d'eau}$ $N = 180$ $R = 35,7$ Ech. : 1/50 et 1/250

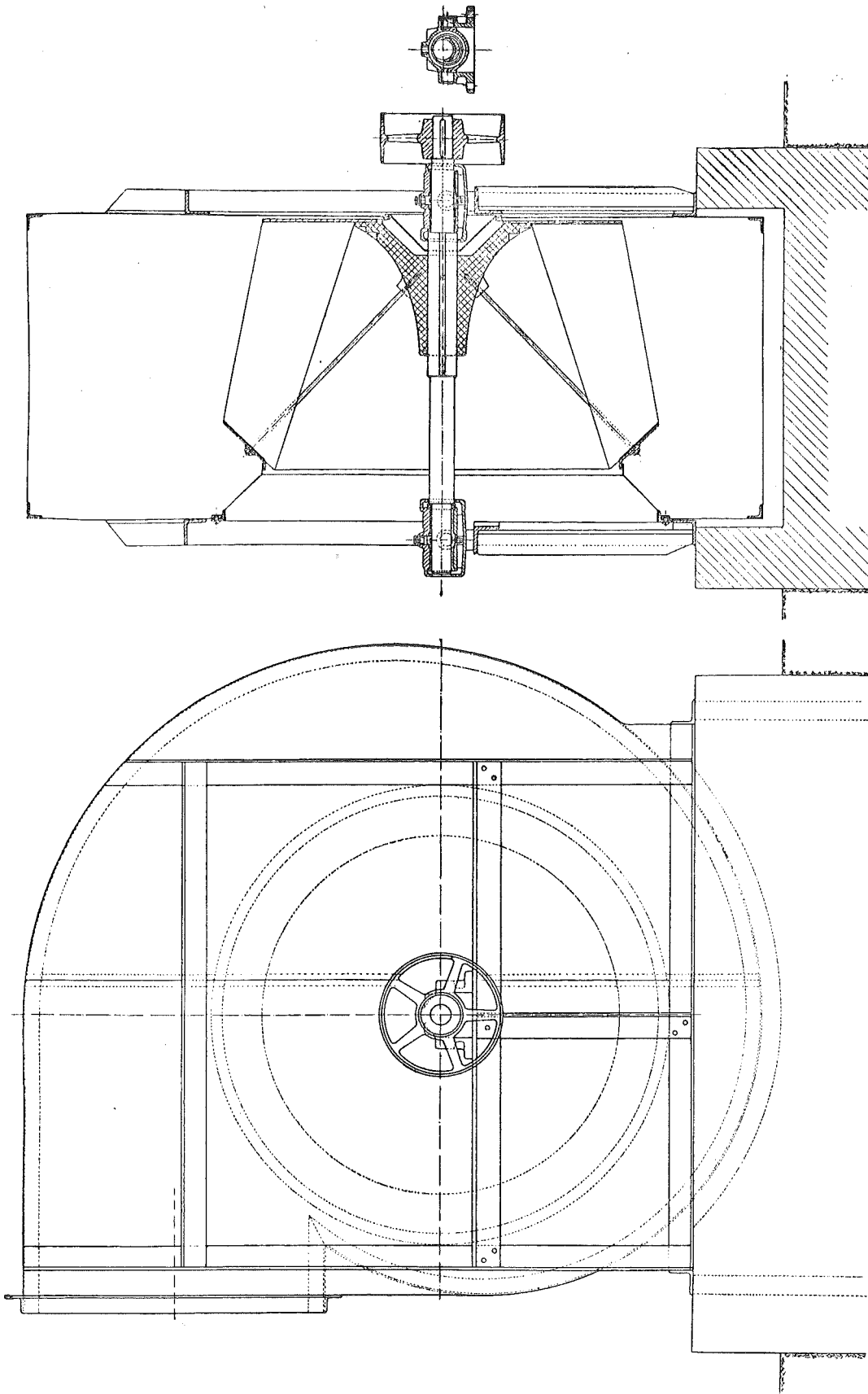


FIG. 88. $Q = 1100 \text{ m}^3/\text{min}$ $H' = 39,5 \text{ m d'air}$ $N = 250$ $R = 50$ $\text{Ech.} : 1/25$

TURBO-COMPRESSEURS

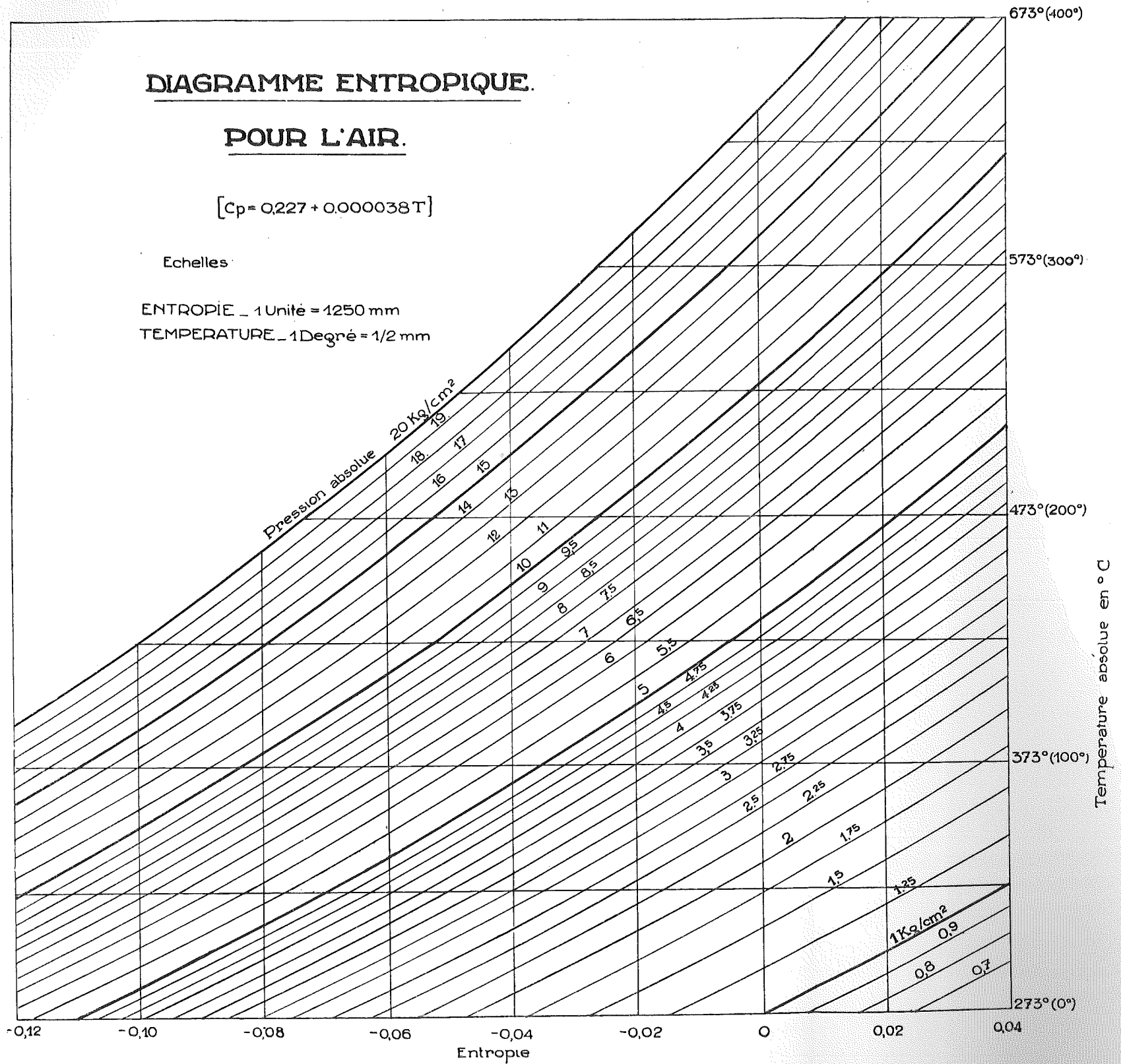


FIG. 89.

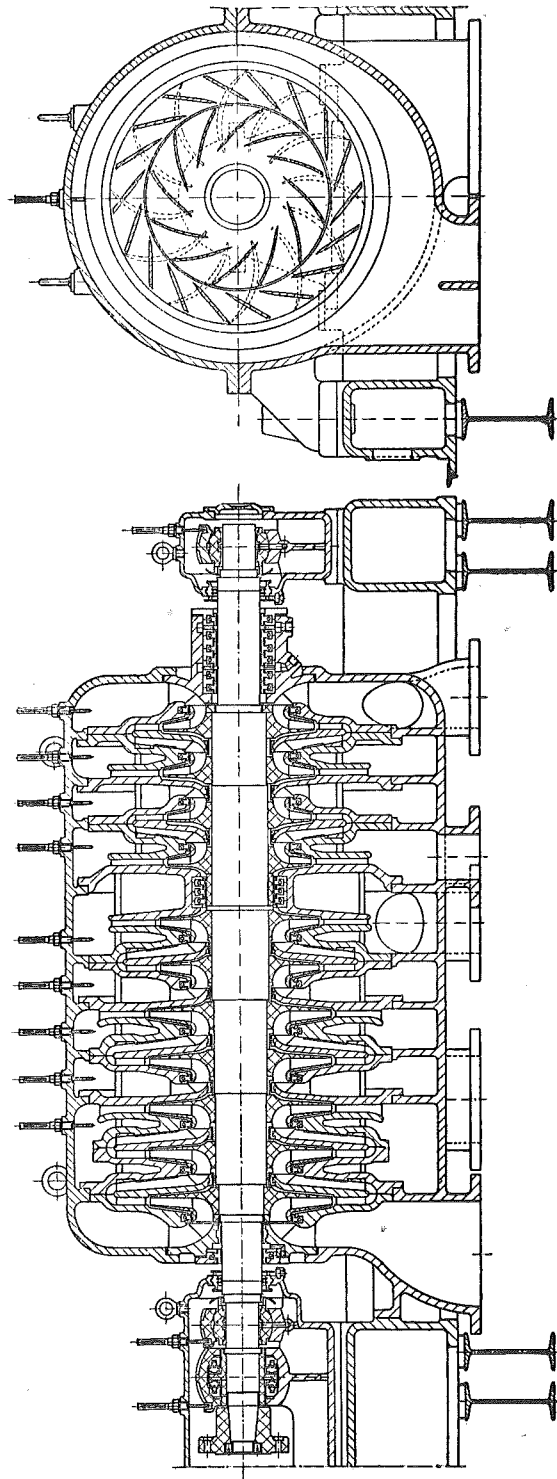


FIG. 91.

$Q_{asp.} = 120 \text{ m}^3/\text{min}$ $7 \text{ kg/cm}^2 \text{ eff.}$ $N = 6750$ Ech. : 1/25

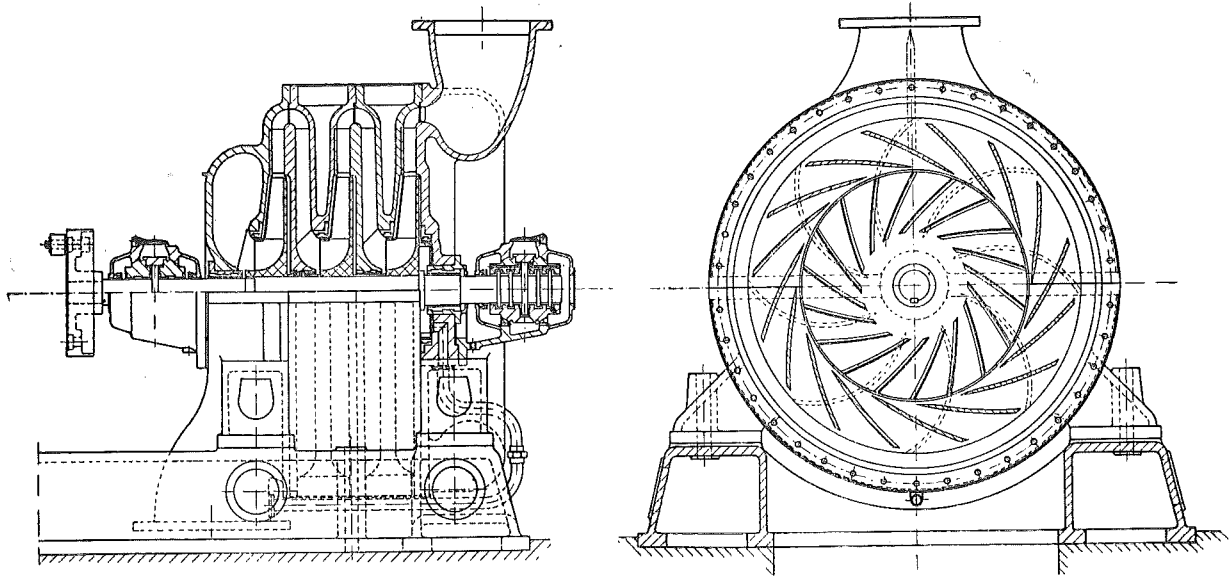


FIG. 90.

$Q = 1,5 \text{ m}^3/\text{sec}$ $h = 3,50 \text{ m d'eau}$ $N = 2920$ Echelle : 1/25

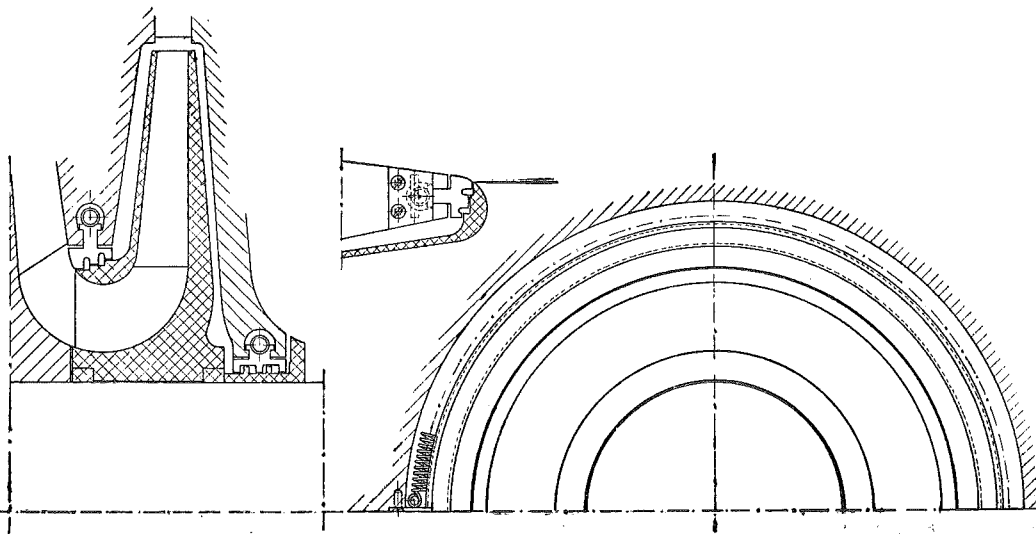


FIG. 92.

Bagues d'étanchéité

TURBINES HYDRAULIQUES

Formules générales :

$$\mathfrak{E}_i = \frac{1}{2g} (c_1^2 - c_2^2) + \int_{2'}^1 v \cdot dp - \mathfrak{E}_f.$$

$$\int_2^1 v \cdot dp + \frac{1}{2g} (u_2^2 - u_1^2) = \frac{1}{2g} (w_2^2 - w_1^2) + \mathfrak{E}_f.$$

$$\mathfrak{E} = \frac{1}{2g} [(c_1^2 - c_2^2) - (w_1^2 - w_2^2) + (u_1^2 - u_2^2)] = \frac{1}{g} (u_1 c_1 \cos \alpha_1 - u_2 c_2 \cos \alpha_2).$$

$$\mathfrak{E}_f = \frac{2}{3} gb \left(\frac{\chi}{\omega} \right)_m s \cdot \frac{w_1^2 + w_1 w_2 + w_2^2}{2g} = \left(\frac{1}{\varphi^2} - 1 \right) \frac{w_2^2}{2g} + \left(\frac{1}{\psi^2} - 1 \right) \frac{w_1^2}{2g}.$$

Hauteur manométrique :

$$H' = (h_1 + h_2) - (\mathfrak{E}_f' + \mathfrak{E}_f'') = v (p_e - p_s) + (h' + h'') + \frac{1}{2g} (c_e^2 - c_s^2).$$

$$H' = \frac{1}{2g} (c_1^2 - c_2^2) - \frac{1}{2g} (w_1^2 - w_2^2) + \frac{1}{2g} (u_1^2 - u_2^2) + \mathfrak{E}_1 + \mathfrak{E} + \mathfrak{E}_2.$$

Coefficient de vitesse :

$$x_1 = \frac{u_1}{\sqrt{2gH'}}.$$

Coefficient manométrique :

$$M \equiv \frac{2gH'}{c_1^2} = A + Bx + Cx^2$$

avec :

$$x = \frac{u_1}{c_1}.$$

$$A = \frac{1}{\varphi_1^2} - \left(2 - \frac{1}{\psi^2} \right) - n^2 \left(2 - \frac{1}{\psi_1^2} - \frac{1}{\varphi^2} \right).$$

$$B = 2 \left[\left(2 - \frac{1}{\psi^2} \right) \cos \alpha_1 - mn \cos \beta_2 \left(2 - \frac{1}{\psi_1^2} \right) \right].$$

$$C = \left(\frac{1}{\psi^2} - 1 \right) - \left(3 - \frac{1}{\psi_1^2} \right) m^2.$$

Coefficient de puissance :

$$P \equiv \frac{g\mathfrak{E}_i}{c_1^2} = x (a - bx).$$

$$a = \cos \alpha_1 - mn \cos \beta_2.$$

$$b = m^2.$$

Rendement indiqué :

$$\eta_i = 2 \frac{P}{M}.$$

Rendement organique :

$$\eta_o = 1 - \frac{N_0}{N_i} = 1 - \frac{\frac{1}{2\pi} \cdot g \cdot \frac{K}{\delta} \cdot \frac{d}{2r_1} \cdot \frac{xM}{2gH'} + \frac{2}{5} bgx^3}{P \cdot \varepsilon \cdot \sin \alpha_1}.$$

Fuites :

$$\frac{f}{Q} = 2 \cdot \frac{r'_2}{r_1} \cdot \frac{j}{r_1 \varepsilon \cdot \sin \alpha_1} \cdot \frac{k_2 \sqrt{Mr}}{r_1}.$$

Coefficients caractéristiques :

$$R \equiv \frac{N_i N_2}{\delta (2g)^{3/2} H'^{5/2}} = \frac{\overline{60}^2}{75} \cdot \frac{1}{\pi} \cdot \varepsilon k' k'' \cdot \sin \alpha_1 \cdot \frac{Px^2}{M^{5/2}}.$$

$$R' \equiv \frac{QN^2}{(2gH')^{3/2}} = \frac{\overline{60}^2}{2\pi} \cdot \varepsilon k' k'' \sin \alpha_1 \cdot \frac{x^2}{M^{3/2}}.$$

Coefficient caractéristique, turbine Pelton :

$$R = \frac{N_i N^2}{\delta (2g)^{3/2} H'^{5/2}} = \frac{\overline{60}^2}{75} \cdot \frac{1}{8\pi} \cdot \frac{\varphi_1^5}{k^2} x^2 P.$$

TURBORÉCEPTRICES

Formules générales :

$$\begin{aligned}\mathfrak{E}_i &= \frac{1}{2g} (c_1^2 - c_0^2) + \int_0^1 v \cdot dp + \mathfrak{E}_f \\ \int_1^0 v \cdot dp + \frac{1}{2g} (u_1^2 - u_0^2) &= \frac{1}{2g} (w_1^2 - w_0^2) + \mathfrak{E}_f \\ \mathfrak{E}_i &= \frac{1}{2g} [(c_1^2 - c_0^2) - (w_1^2 - w_0^2) + (u_1^2 - u_0^2)] = \frac{1}{g} (u_1 c_1 \cos \alpha_1 - u_0 c_0 \cos \alpha_0) \\ \mathfrak{E}_f &= \frac{2}{3} gb \left(\frac{\chi}{\omega}\right)_m \cdot s \cdot \frac{w_0^2 + w_0 w_1 + w_1^2}{2g} = \left(\frac{1}{\varphi^2} - 1\right) \frac{w_1^2}{2g} + \left(\frac{1}{\psi^2} - 1\right) \frac{w_0^2}{2g}\end{aligned}$$

Hauteur manométrique :

$$\begin{aligned}H' &= (h_1 + h_2) + (\mathfrak{E}_f' + \mathfrak{E}_f'') = v(p_s - p_e) + (h' + h'') + \frac{1}{2g} (c_s^2 - c_e^2) \\ H' &= \frac{1}{2g} (c_1^2 - c_0^2) - \frac{1}{2g} (w_1^2 - w_0^2) + \frac{1}{2g} (u_1^2 - u_0^2) - \mathfrak{E}_1 - \mathfrak{E}_f - \mathfrak{E}_2\end{aligned}$$

Coefficient de débit :

$$x = \frac{w_1}{u_1}$$

Coefficient manométrique :

$$M \equiv \frac{2gH'}{u_1^2} = A + Bx + Cx^2$$

avec :

$$\begin{aligned}A &= \left(3 - \frac{1}{\psi_1^2}\right) - m^2 \left(\frac{1}{\varphi_1^2} + 1\right) \\ B &= 2 \left[\left(2 - \frac{1}{\psi_1^2}\right) \cos \beta_1 - \frac{1}{\varphi_1^2} \cdot mn \cos \beta_0 \right] \\ C &= \left(2 - \frac{1}{\varphi^2} - \frac{1}{\psi_1^2}\right) - \left(\frac{1}{\varphi_1^2} + \frac{1}{\psi^2} - 2\right) n^2\end{aligned}$$

Coefficient de puissance :

$$P \equiv \frac{g\mathfrak{E}_i}{u_1^2} = a + bx$$

$$a = 1 - m^2$$

$$b = \cos \beta_1 - mn \cos \beta_0$$

Rendement indiqué :

$$\eta_i = \frac{1}{2} \cdot \frac{M}{P}$$

Rendement organique :

$$\eta_0 = \frac{1}{1 + \frac{N_o}{N_i}}$$

avec :

$$\frac{N_o}{N_i} = \frac{\frac{1}{2\pi} \cdot g \cdot \frac{K}{\delta} \cdot \frac{d}{2r_1} \cdot \frac{M}{2gH'} + \frac{2}{5} bg}{xP \cdot \varepsilon \sin \beta_1}$$

Fuites :

$$\frac{f}{Q} = 2 \cdot \frac{r'_2}{r_1} \cdot \frac{j}{r_1} \cdot \frac{k_2 \sqrt{Mr}}{\varepsilon \cdot x \cdot \sin \beta_1}$$

Coefficient caractéristique :

$$R \equiv \frac{QN^2}{(2gH')^{3/2}} = \frac{60^2}{2\pi} \cdot \varepsilon k' k'' \sin \beta_1 \cdot \frac{x}{M^{3/2}}$$

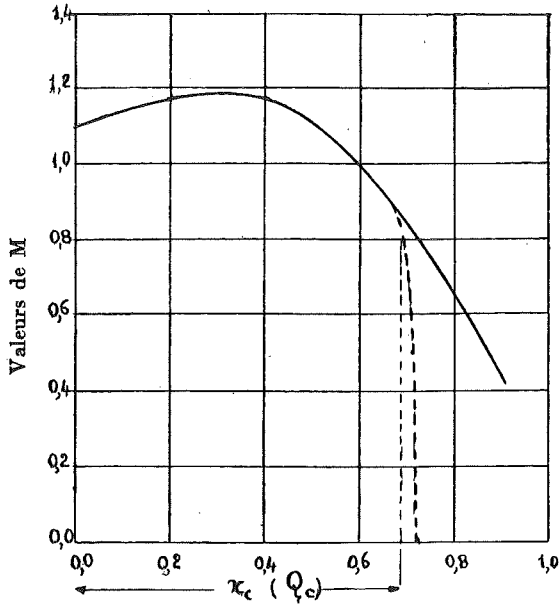


FIG. 28

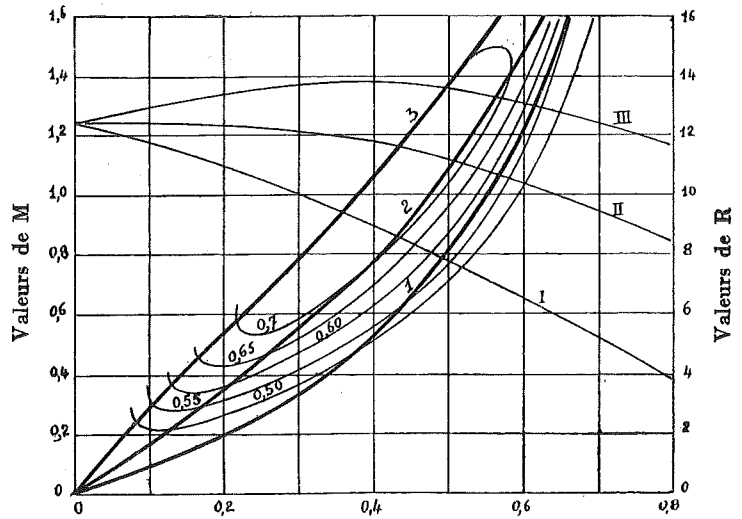


FIG. 29

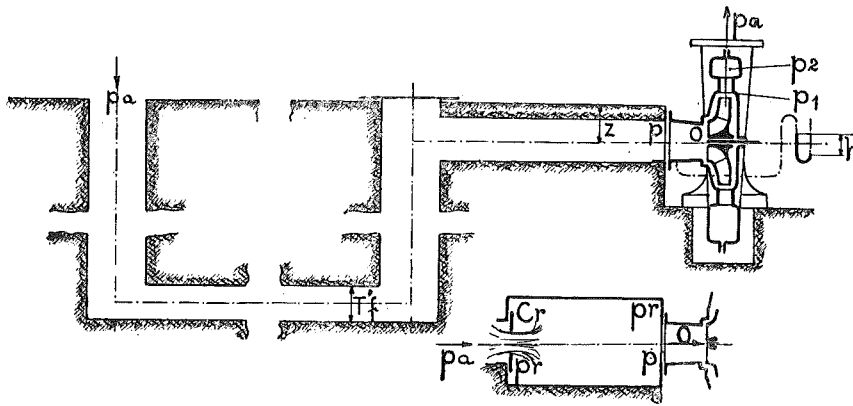


FIG. 30

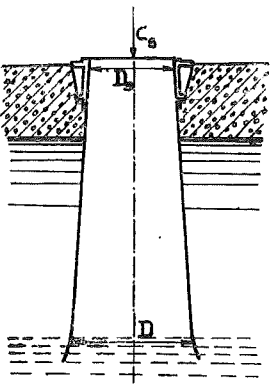


FIG. 56

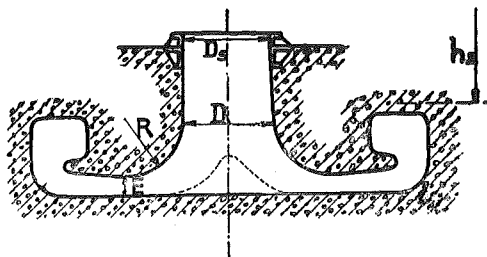


FIG. 57

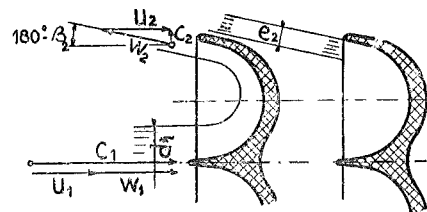


FIG. 59

$$m = \frac{z_0}{z_1}$$

$$\varepsilon = \frac{l_1}{z_1}$$

$$\gamma = \frac{l_0}{l_1}$$

Notes from ...

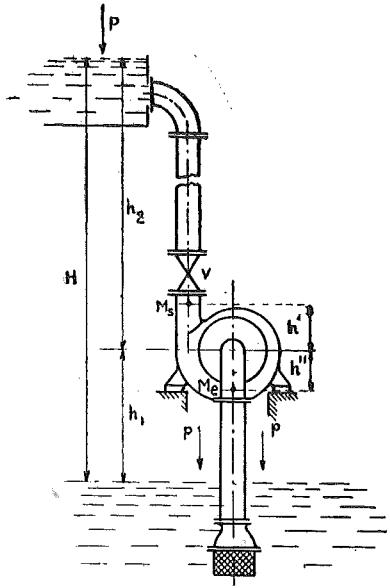


FIG. 6 et 16

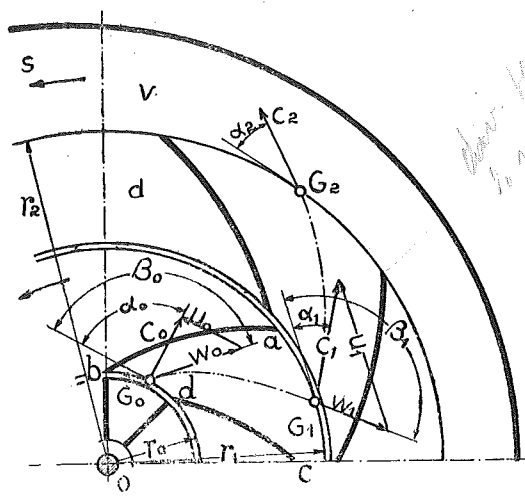


FIG. 7 et 18

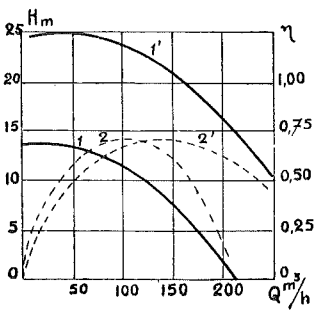
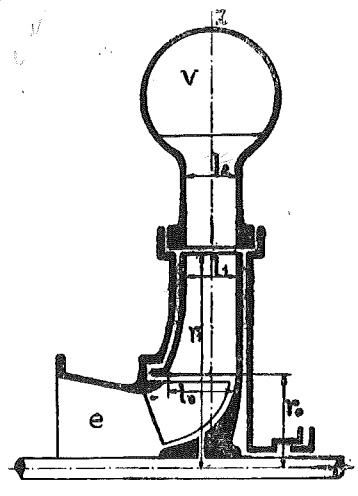


FIG. 8

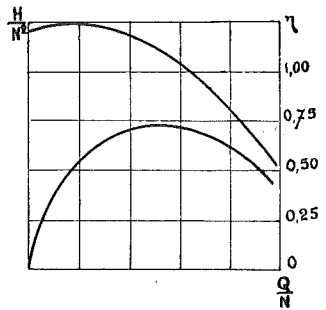


FIG. 9

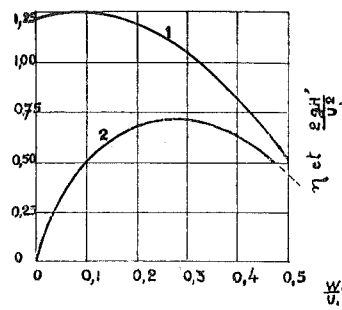


FIG. 10

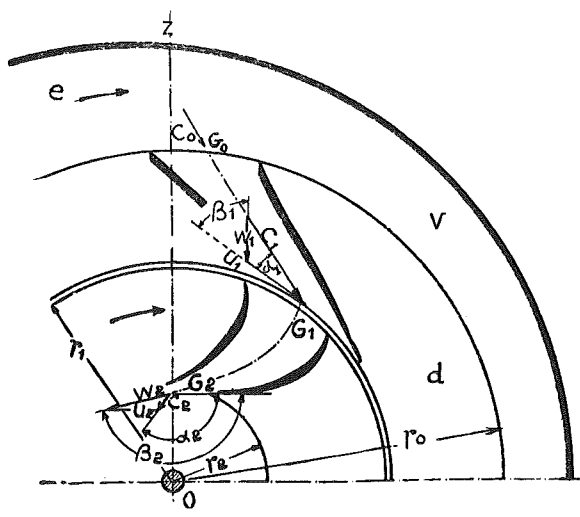


FIG. 15

