ТОМСКИЙ
ПОЛИТЕХНИЧЕСКИЙ
УНИВЕРСИТЕТ

NPP STEAM GENERATORS

Hydraulic processes in SGs. Pressure drops in two-phase flows

Lecture plan

1. Calculation of hydraulic resistances (frictional and local)
2. Pressure drop in flow over the tube bundles
3. Calculation of pressure drop due to flow acceleration
4. Static pressure drop (drop due to vertical head elevation or drop)

Friction drop for flow in the channel

- Homogeneous flow model.
- Separated flow model (Lockhart-Martinelli method)

Calculation of friction pressure drop for homogeneous flow model

TSKTI method

For circular tubes

$$\Delta p_{fr} = \xi_{fr} \cdot \frac{L}{d_h} \cdot \frac{(\rho w)^2}{2 \cdot \rho'} \cdot \left[1 + \psi \cdot \left(\frac{\rho'}{\rho''} - 1 \right) \right]$$

Here $\psi = f(p, \rho w, x)$ is determined by means of nomographs;

ξ_{fr} – friction factor of a single-phase flow for equal flow rate of fluid;

L, d_h – length and hydraulic diameter of the channel;

ρ', ρ'' - density of saturated water and steam

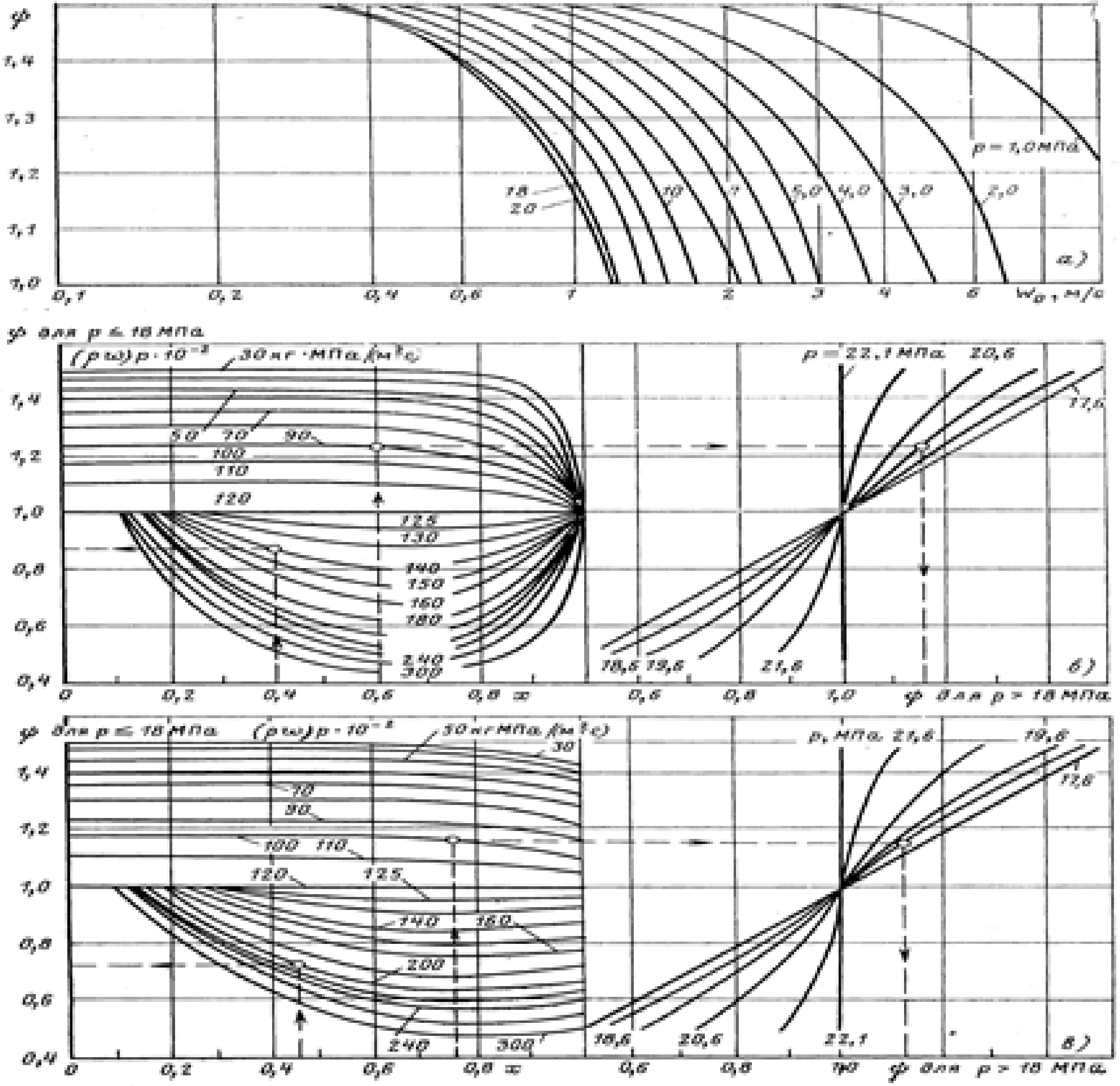

Рис. 2.5. Значения коэффициента φ для $x < 0{,}7$ и $w_0 < 10$ м/с (а), для необогреваемых труб при $w_0 \geq 10$ м/с (б), обогреваемых труб при $w_0 \geq 10$ м/с (в)

Calculation of friction pressure drop for separated flow model

Lockhart-Martinelli method

$$\left(\frac{dp}{dz}\right) = \Phi_L^2 \cdot \left(\frac{dp}{dz}\right)_L \quad или \quad \left(\frac{dp}{dz}\right) = \Phi_V^2 \cdot \left(\frac{dp}{dz}\right)_V$$

Here

$$-\left(\frac{dp}{dz}\right)_V = \frac{2 \cdot \xi'' \cdot x^2 \cdot (\rho\omega)^2}{d \cdot \rho''};$$

$$-\left(\frac{dp}{dz}\right)_L = \frac{2 \cdot \xi' \cdot (1-x)^2 \cdot (\rho\omega)^2}{d \cdot \rho'}$$

Calculation of friction pressure drop for separated flow model

Lockhart-Martinelli method

$$\mathrm{Re}_V = \frac{x \cdot d \cdot (\rho\omega)}{\mu''};$$

$$\mathrm{Re}_L = \frac{(1-x) \cdot d \cdot (\rho\omega)}{\mu'}$$

$$\xi = \frac{16}{\mathrm{Re}} \qquad npu\ \mathrm{Re} \le 2000;$$

$$\xi = 0,11 \cdot \left(\frac{\Delta}{d} + \frac{68}{\mathrm{Re}} \right)^{0,25} \qquad npu\ \mathrm{Re} > 2000$$

Calculation of friction pressure drop for separated flow model

Lockhart-Martinelli method

$$X^2 = \frac{(dp/dz)_L}{(dp/dz)_V}$$

$$\Phi_L^2 = 1 + \frac{C}{X} + \frac{1}{X^2};$$
$$\Phi_V^2 = 1 + C \cdot X + X^2$$

Regime (water-steam)	C
Turbulent-Turbulent	20
Laminar-Turbulent	12
Turbulent-Laminar	10
Laminar-Laminar	5

Order of friction pressure drop calculation by the Lockhart-Martinelli method

1. Reynolds number for steam Re_V and water Re_L ;
2. Friction factor for steam ξ_V and water ξ_L;
3. Specific pressure drop for steam $(dp/dz)_V$ and water $(dp/dz)_L$;
4. Coefficient X^2;
5. Coefficient C;
6. Complex Φ^2 for steam and water;
5. Specific pressure drops for steam-water mixture (dp/dZ);
6. Total pressure drop due to friction for steam-water mixture

$$\Delta p_{mp} = \left(dp/dz\right) \cdot L$$

Here L – channel length

Pressure drop in the channel due to local resistances

$$\Delta p_{loc} = \Delta p_{loc.sph} \cdot \left[1 + x \cdot \left(\frac{\rho'}{\rho''} - 1 \right) \right]$$

Here $\Delta p_{loc.sph}$ - local resistance of a single-phase flow for equal flow rate of the medium of density *ρ';*
x – steam quality

Drops due to acceleration in two-phase flows

$$\Delta p_{ass} = \rho'_{out}\, w_{0,out}^2 \left[1 + x_{out}\left(\frac{\rho'_{out}}{\rho''_{out}} - 1\right)\right] - \rho'_{in}\, w_{0,in}^2 \left[1 + x_{in}\left(\frac{\rho'_{in}}{\rho''_{in}} - 1\right)\right]$$

Here x_{out}, x_{in} – final and initial steam quality;

$w_{0,out}$, $w_{0,in}$ – final and initial values of circulation rate;

ρ'_{out}, ρ'_{in} – final and initial saturated water density;

ρ''_{out}, ρ''_{in} – final and initial saturated steam density

Static pressure drop (drop due to vertical head variation) in two-phase flows

Static pressure drop in the channel is defined as the sum of scales of the fluid columns for all of the channel sections.

Static pressure drop for flow in the j-section is given by the equation

$$\Delta p_{нив,j} = \left[\overline{\varphi}_j \cdot \rho'' + \left(1 - \overline{\varphi}_j \right) \cdot \rho' \right] \cdot h_j \cdot g$$

average actual volumetric void fraction in j-section

saturated steam density

saturated water density

height of the j-section

Static pressure drop (drop due to vertical head variation) in two-phase flows

Static pressure drop in the channel is defined as the sum of scales of the fluid columns for all of the channel sections.

Static pressure drop for flow in the j-section is given by the equation

$$\Delta p_{нив,j} = \left[\varphi_{avr.j} \cdot \rho'' + \left(1 - \varphi_{avr.j}\right) \cdot \rho' \right] \cdot h_j \cdot g$$

Here j is channel section number;

$\varphi_{avr.j}$ is average actual volumetric void fraction in j-section;

ρ'' is saturated steam density;

ρ' is saturated water density;

h_j is height of the j-section

Static pressure drop (drop due to vertical head variation) in two-phase flows

Note. Static pressure drop is considered to be positive for upstream sections and negative for downstream sections.

Thank you for attention