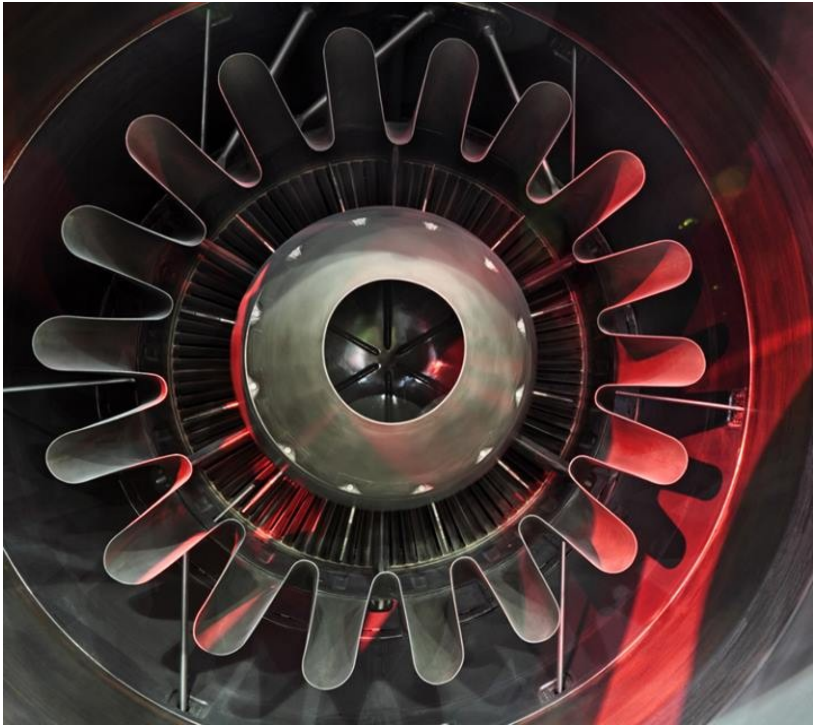
8. Engine Component Operation:

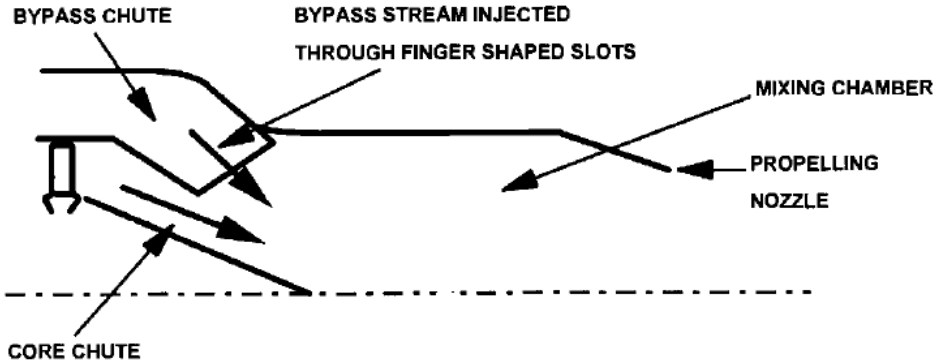
Mixer

For turbofan engines a mixer may be employed to combine the hot and cold streams prior to exhausting through a common propelling nozzle.



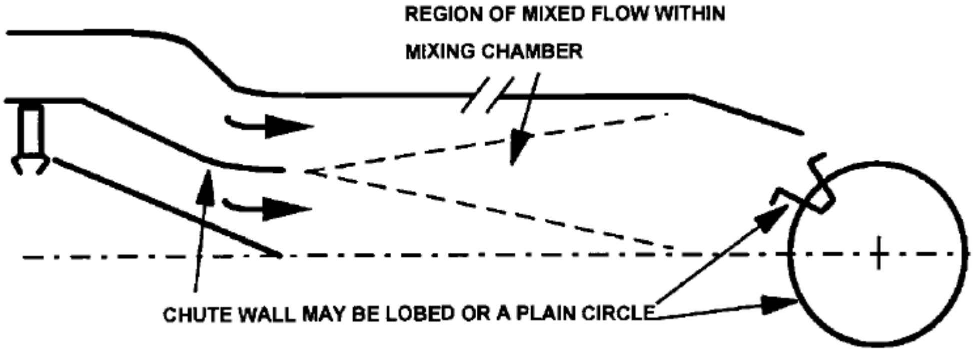
Configurations

Injection mixer

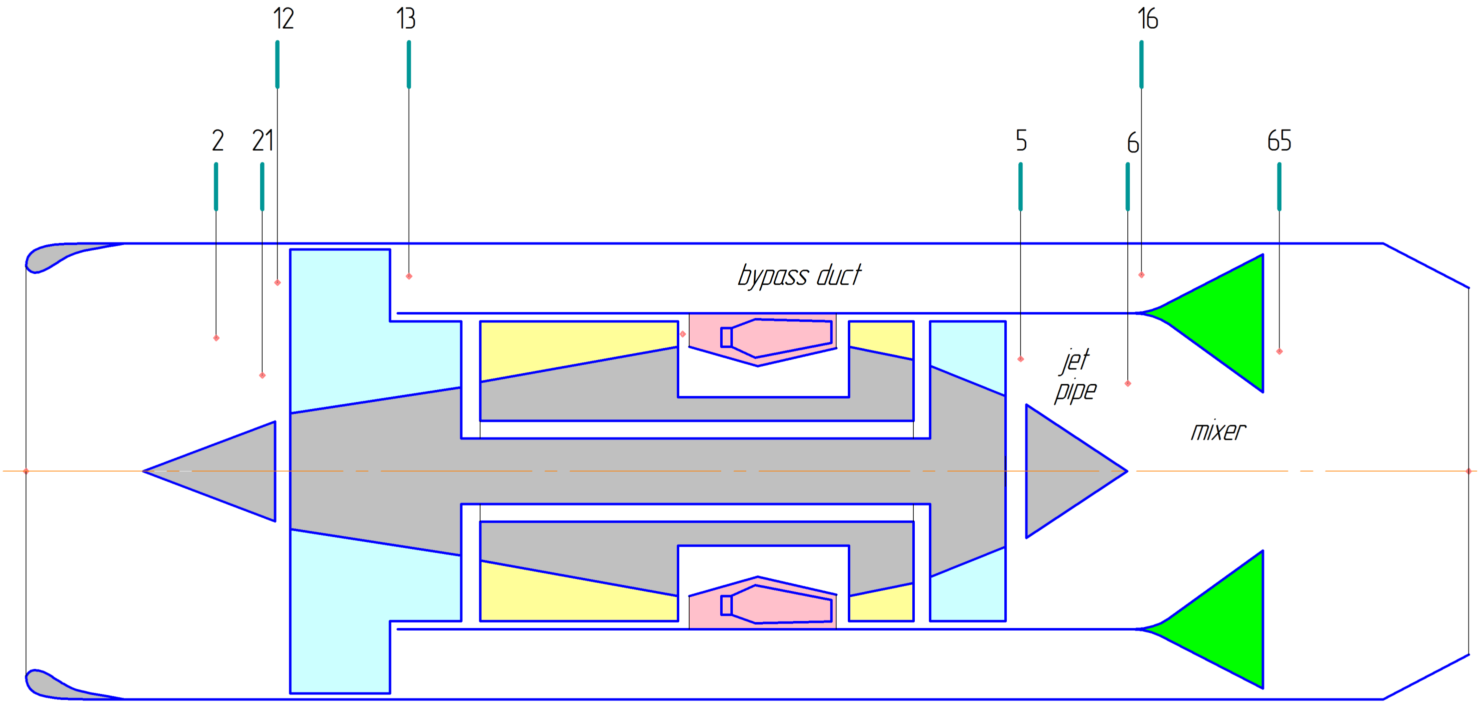


Lobed annular mixer

Plain annular mixer



Calculation Scheme



Input data:

σ_{5-6}	- jet pipe total pressure loss factor;
σ_{bypass}	- bypass total pressure loss factor;
σ_{mixer}	- mixer total pressure loss factor;
λ_6	- critical velocity ratio (0,3 … 0,5)

Parameters at station 6:

$$T_6^* = T_5^*\,;$$

$$p_6^* = p_5^* \cdot \sigma_{5-6}\,;$$

$$\nu_6 = \nu_5\,;$$

$$G_6 = G_5\,.$$

Parameters at station 16:

$$T_{16}^* = T_{13}^*\,;$$

$$p_{16}^* = p_{13}^* \cdot \sigma_{\text{bypass}}\,;$$

$$G_{16} = G_{13}\,.$$

Mass flow rate G_{65} :

$$G_{65} = G_6 + G_{16} .$$

Relative mass flow rate ν_{65} :

$$\nu_{65} = \frac{G_{65}}{G_2} = \frac{G_6}{G_{21} \cdot (1+m)} + \frac{G_{16}}{G_{21} \cdot (1+m)} = \frac{\nu_6 + m}{1+m} .$$

Total temperature of the mixture is determined by the equation of energy conservation:

$$I_{65}^{*}=I_{6}^{*}+I_{16}^{*}\,;$$

$$i_{65}^{*}\cdot G_{65}=i_{6}^{*}\cdot G_{6}+i_{16}^{*}\cdot G_{16}\,;$$

$$c_{\mathrm{p}.cg}\cdot T_{65}^{*}\cdot G_{65}=c_{\mathrm{p}.cg}\cdot T_{6}^{*}\cdot G_{6}+c_{\mathrm{p}.a}\cdot T_{16}^{*}\cdot G_{16}\,;$$

$$T_{65}^{*}=\frac{c_{\mathrm{p}.cg}\cdot T_{6}^{*}\cdot \nu_{6}+c_{\mathrm{p}.a}\cdot T_{16}^{*}\cdot m}{c_{\mathrm{p}.cg}\cdot\left(\nu_{6}+m\right)}\,.$$

When mixing the total temperature is averaged over the mass of the working fluid.

Total pressure at the outlet of the mixer is determined on the basis of the momentum equation for stations at the inlet and exit of the cylindrical mixing duct. In this case, the axial component of external forces exerted by the cylindrical walls is equal to zero:

$$\Delta\Phi=\Phi_{65}-\left(\Phi_6+\Phi_{16}\right)=0\,;$$

$$\Phi_{65}=\left(\Phi_6+\Phi_{16}\right)\,;$$

$$p^*_{65s}\cdot F_{65}\cdot f\left(\lambda_{65}\right)=p^*_6\cdot F_6\cdot f\left(\lambda_6\right)+p^*_{16}\cdot F_{16}\cdot f\left(\lambda_{16}\right)\,.$$

Combination of critical velocity ratios at mixer inlets (λ_6 and λ_{16}) corresponds to equality of static pressures:

$$p_6=p_{16}\,;$$

$$\pi\left(\lambda_{16}\right)=\frac{p^*_6}{p^*_{16}}\cdot\pi\left(\lambda_6\right)\,.$$

Areas F_6 and F_{16} at the mixer inlet:

$$F_6 = \frac{G_6 \cdot \sqrt{T_6^*}}{m_{cg} \cdot p_6^* \cdot q(\lambda_6)};$$

$$F_{16} = \frac{G_{16} \cdot \sqrt{T_{16}^*}}{m_a \cdot p_{16}^* \cdot q(\lambda_{16})}.$$

Area F_{65} at the mixer outlet:

$$F_{65} = F_6 + F_{16}.$$

Critical velocity ratio λ_{65} can be determined using the momentum equation expressed by isentropic flow function $z(\lambda)$:

$$\Phi_{65}=\left(\Phi_6+\Phi_{16}\right);$$

$$G_{65}\cdot \hat{a}_{65}\cdot z\left(\lambda_{65}\right)=G_6\cdot \hat{a}_6\cdot z\left(\lambda_6\right)+G_{16}\cdot \hat{a}_{16}\cdot z\left(\lambda_{16}\right);$$

$$z\left(\lambda_{65}\right)=\frac{G_6\cdot \hat{a}_6\cdot z\left(\lambda_6\right)+G_{16}\cdot \hat{a}_{16}\cdot z\left(\lambda_{16}\right)}{G_{65}\cdot \hat{a}_{65}}.$$

Total pressure at the outlet of the mixer p^*_{65}:

$$p^*_{65}=p^*_{65\,s}\cdot\sigma_{\text{mixer}}=\frac{p^*_6\cdot F_6\cdot f\left(\lambda_6\right)+p^*_{16}\cdot F_{16}\cdot f\left(\lambda_{16}\right)}{F_{65}\cdot f\left(\lambda_{65}\right)}\cdot\sigma_{\text{mixer}}.$$

Neglecting the value difference of function $f(\lambda)$ at $\lambda = 0{,}4 \ldots 0{,}6$:

$$\overset{*}{p}_{65} = \frac{\overset{*}{p}_6 \cdot F_6 + \overset{*}{p}_{16} \cdot F_{16}}{F_{65}} \cdot \sigma_{\text{mixer}} \,.$$

The total pressure is averaged over the flow area.

For simplified calculation the simplest form may be used:

$$\overset{*}{p}_{65} = \frac{\overset{*}{p}_6 \cdot \nu_6 + \overset{*}{p}_{16} \cdot m}{\nu_6 + m} \,.$$